United States Patent [19]

Mesek

[11] **3,838,694**

[45] **Oct. 1, 1974**

[54] **DIAPER WITH BACK-TO-BACK TRANSITION WEB FACING**

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[73] Assignee: **Johnson & Johnson,** New Brunswick, N.J.

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[52] **U.S. Cl.** ..... **128/287,** 128/290 W

[51] **Int. Cl.** **A61f 13/16**

[58] **Field of Search** 128/284, 286, 287, 290; 161/116, 151, 155, 164, 169, 170

[56] **References Cited**

UNITED STATES PATENTS

3,063,454	11/1962	Coates et al.	128/290 W
3,180,335	4/1965	Duncan et al.	128/287
3,315,676	4/1967	Cooper	128/287
3,612,055	10/1971	Mesek et al.	128/287
3,663,348	5/1972	Liloia et al.	128/284
3,768,480	10/1973	Mesek et al.	128/287

Primary Examiner—Aldrich F. Medbery

[57] **ABSTRACT**

A disposable multi-layer diaper includes at one surface a porous fibrous facing layer to be brought into contact with the infant's skin, and includes at the other surface, a water-impervious backings sheet, with an absorbent batt being interposed between the facing layer and backing sheet. The facing layer is comprised of two half-thickness portions, the outer half-thickness portion to be positioned adjacent the infant's skin, being readily separable from the inner half-thickness portion, and from the remainder of the diaper, so that the outer half-thickness portion and any fecal matter thereon can be flushed down a standard toilet separate and apart from the remainder of the diaper including the non-degradable water-impervious backing sheet. The outer half-thickness portion is characterized by a given overall concentration of long and short fibers, the outer face having a concentration of long fibers in excess of the given overall concentration of long fibers in the half-thickness portion, with the long fibers decreasing in concentration closer to the inner face of the outer half-thickness portion. In the preferred embodiment, the inner half-thickness portion of the facing layer is of the same fiber concentration structure as the first half-thickness portion and through-bonded thereto with the short fiber enriched faces in juxtaposition. The concentration of short fibers at the interior of the facing layer provides a layer of weakness therein which permits the facing layer to be manually delaminated along the short fiber plane for the disposal of fecal matter.

24 Claims, 5 Drawing Figures

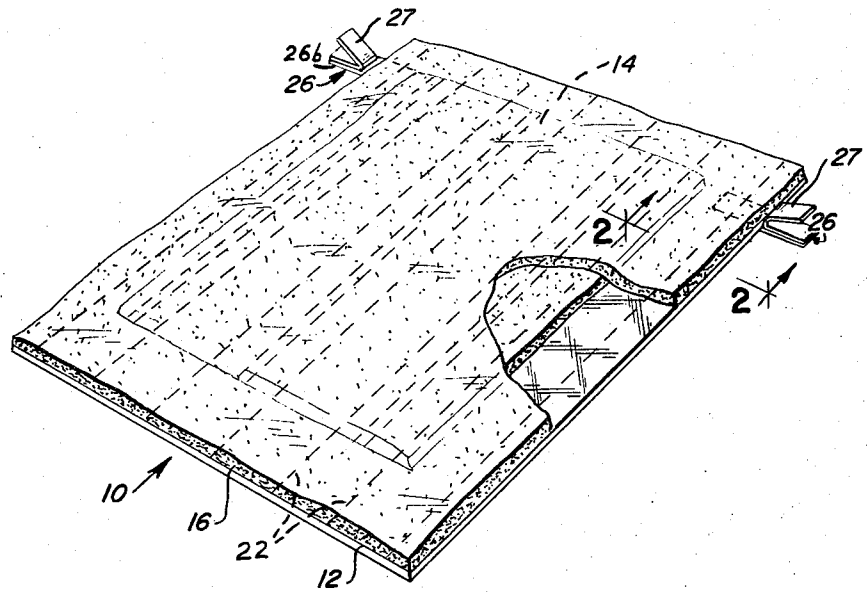


FIG. 1

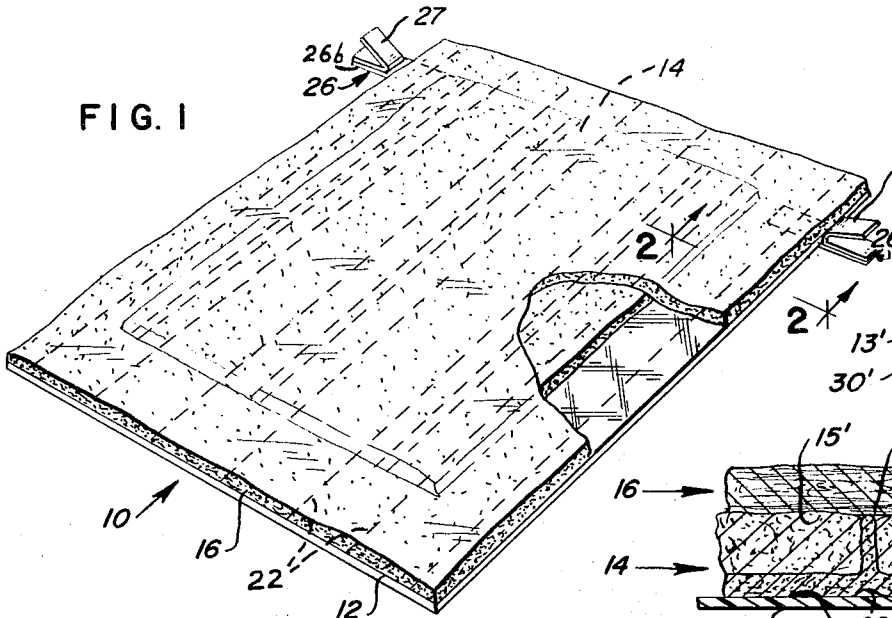


FIG. 4

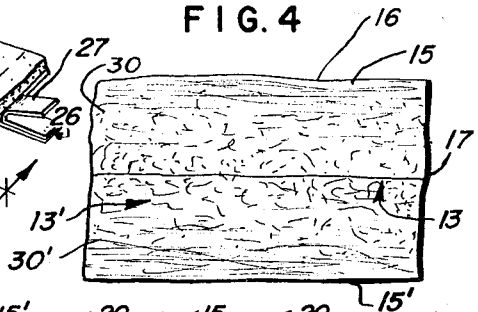


FIG. 3

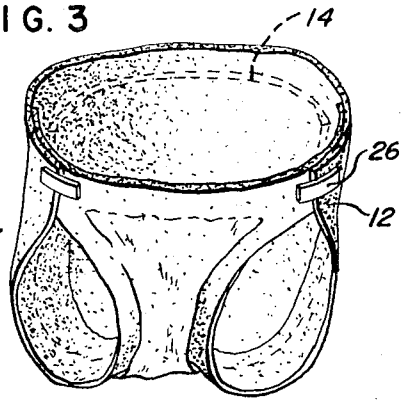


FIG. 2

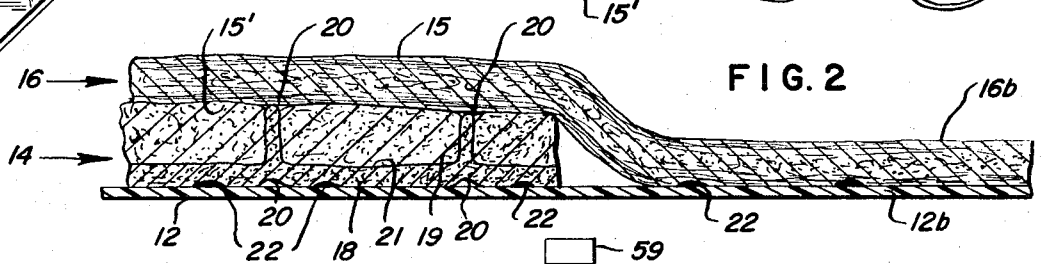
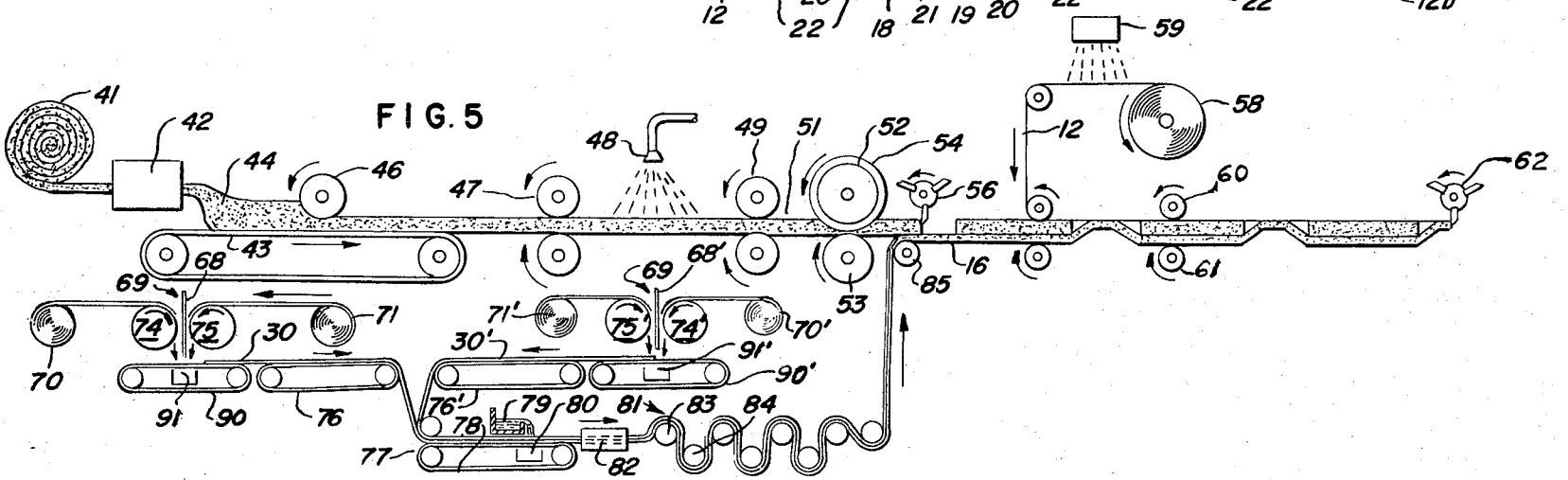


FIG. 5



DIAPER WITH BACK-TO-BACK TRANSITION WEB FACING

BACKGROUND OF THE INVENTION

This invention relates to an improved disposable diaper which has an air laid fibrous facing layer that has improved strength and smoothness and a portion of which may be easily and readily delaminated from the remainder of the diaper to enable fecal matter on the delaminatable portion of the diaper to be disposed of independently from the other diaper components.

Disposable diapers have met with increased commercial acceptance in the recent past due both to their convenience and to their improved functional characteristics, as compared to cloth diapers. A typical disposable diaper includes a porous facing layer which is placed adjacent to the infant's skin, an absorbent pad or batt to retain body fluid that passes through the facing layer, and a moisture impervious backing sheet to confine absorbed fluids within the batt.

One of the problems encountered by the prior art has been the inability to provide a suitable light weight inexpensive facing material which is pliable, soft, comfortable and non-irritating to infant's skin, while at the same time having adequate strength and dimensional stability, and the desired degree of porosity and water wettability. A further problem which has more recently become a matter of concern is the disposal of disposable diapers containing fecal matter. With the growing concern for pollution of the environment, various regulations have been enacted by certain municipal governing bodies prohibiting the disposal of human fecal matter through solid waste disposal systems. As a result, it has been necessary to cleanse the disposable diaper of fecal matter prior to its disposal which presents asthetic and sanitary problems.

Certain prior art patents have disclosed means for separating fecal matter from the used diaper, however, they require either the separation of the biodegradable components of the diaper, i.e., facing and batt from the impervious backing sheet or removal of the entire facing layer from the impervious backing sheet. Still other patents have disclosed absorbent inserts which may be readily removed by an envelope-like liner for disposal.

Duncan et al., U.S. Pat. No. 3,180,335 discloses a disposable diaper in which the impervious backing sheet is separated from the absorbent material by stripping the absorbent material from its marginal adhesive areas on the backing sheet. The Duncan et al. diaper consists of a water-impervious backing sheet and an absorbent pade centrally disposed thereon. The pad includes multiple plies of creped cellulose wadding and is enclosed on one surface (to be positioned against the infant's skin) and on all four sides by a non-woven facing layer. The facing layer is adhesively attached to the bottom face of the plies of wadding, and the marginal side and end portions of the facing layer, which are in juxtaposition with the water-impervious backing sheet, are adhered thereto.

After the diaper has been used and removed from the infant, the absorbent pad including the facing layer, is stripped from its adhesive attachment to the backing sheet. The pad is then dipped several times in a toilet until a major portion of the creped wadding is repulped and disposed of in the water. The toilet is then flushed while the remaining portions of the pad are held and then these remaining portions (facing layer and creped plies) are flushed away. The Duncan et al. diaper achieves strippability at a sacrifice to structural stability since the components are adhered to one another in only the marginal portions. This type of adherence may produce areas of non-contact between the pad and the backing sheet so that urine will pool on the backing sheet when the pad separates therefrom. Additionally, since all of the absorbent material is stripped away from the backing sheet, a large amount of bulk must be flushed into the sewage system which may result in clogging.

Hermanson et al., U.S. Pat. No. 2,649,859, discloses a diaper with a water-impervious backing sheet on which several creped cellulose sheets are centrally disposed. A facing sheet covers the creped plies and is adhered to over-turned side portions of the backing sheet. In this manner, the backing sheet and facing layer form an envelope to contain the creped sheets. The diaper of the Hermanson et al. patent is open at each end, and the creped sheets may be sealed at their sides. When the diaper is to be disposed of, the facing sheet and crepe sheets are grasped at one end of the diaper and are torn from the backing sheet to be disposed of in a toilet bowl.

As with the Duncan et al. diaper, the Hermanson et al. diaper requires the disposal of a large bulk of absorbent material which can result in clogging problems. Although the creped sheets in Hermanson et al. may be sealed along their sides, the pooling problem, discussed above, may also be present. Moreover, the separation of the absorbent material from the backing sheet is difficult since the area of bonding at the sides and the overlapping of the backing sheet on the facing layer may result in an irregular tear line of the facing layer.

The problem of providing a facing material of suitable strength and smoothness at low cost has been met with some success. Mesek et al., U.S. Pat. No. 3,612,055 discloses a diaper with a facing layer made of a uniform mixture of long and short fibers, bonded together with a resinous binder material and containing a wetting agent to provide the desired degree of wettability to the facing layer. Such a facing layer with a uniform mixture of long and short fibers utilizes the short fibers for economy and the long fibers for strength and smoothness. It does not, however, utilize the long fibers in the facing material to maximum advantage since a substantial portion of the long fibers are in the interior portion of the facing material where they contribute nothing to surface smoothness and only partially to the strength of the material.

A recent improvement in diapers involves the utilization of a facing fabric comprising a mixture of long and short fibers with a concentration of long fibers (above the overall concentration of long fibers in the total facing layer) at the outer surface of the facing layer. Such a concentration of long fibers at the outermost face of the facing layer provides added surface smoothness, provides strength where it is most needed and utilizes the long fibers in the facing material to greater effectiveness. Commonly owned, copending U.S. Pat. application Ser. No. 260,557 filed June 7, 1952 (now U.S. Pat. No. 3,768,480 dated Oct. 30, 1973), discloses such diapers, and its disclosure is incorporated herein by reference.

SUMMARY OF THE INVENTION

The present invention provides a diaper with a facing layer of nonwoven material, a portion of which may be easily delaminated, from the remainder of the diaper structure for independent removal and disposal of fecal matter. This result is accomplished by a facing layer in the form of a multi-sectioned or sandwich-like fabric having long fibers on its outer faces and an interior portion of short fibers which forms a plane or zone of weakness facilitating delamination.

Nonwoven materials are structures which, in general, consist of an assemblage or web of fibers, joined randomly or systematically by mechanical, chemical or other means. These fibers are well known in the art having gained considerable prominence within the last 25 years or so in the consumer market, industrial-commercial market, and in the hospital field.

Fibers are usually classified according to length, with relatively long or textile length fibers being longer than about one-quarter inch and generally between one-half and two and one-half inches in length. The term "long fibers" as used herein, refers to textile fibers having a length greater than one-quarter inch and the fibers may be of natural or synthetic origin. The term "short fibers," as used herein, refers to paper-making fibers, such as wood-pulp fibers or cotton linters having a length less than about one-quarter inch. While it is recognized that short fibers are usually substantially less costly than long fibers, it is also recognized in many instances that it is desirable to strengthen a short fiber product by including a blend of long fibers therein.

Cost savings in diapers utilizing nonwoven fabrics can be realized by using short fibers. However, due to the low tensile strength of short fiber fabrics, exclusive use of such fibers is impractical since little cohesiveness is present in the fibrous portions of the diaper in absence of a large amount of binder which can adversely affect "feel" and increase overall cost. In the prior art, diapers with facing layers made from short fibers have been undesirable not only due to their low tensile strength, but also due to the increased dusting effect caused by separation of individual fibers from the facing layer. The preparation of nonwoven fabrics for use as diaper facings has heretofore been generally limited to the use of at least a substantial percentage of long fibers because of the inability to make products from short fibers having the strength, light-weight drape and softness and feel characteristics generally associated with fabrics formed of such long fibers.

The diaper of the present invention utilizes as a facing material a multi-sectional fabric having different concentrations of long and short fibers in different thickness portions of the fabric. In order to give the proper feel and comfort characteristics as well as draping, it is desirable to have long fibers at the outer face of the facing which is to be in contact with the infant. And it is likewise desirable to have a long fiber face adjacent to the absorbent batt to maintain integrity of the disposable diaper. A facing layer with only short fibers, or largely short fibers, adjacent the batt and adhered to the backing sheet in its marginal portions is not desirable since the backing is adhered primarily to weak short fibers in these marginal portions and the facing layer may split or separate from the backing during positioning of the diaper on the baby.

In order to have the ability to remove fecal matter from a soiled diaper, it is desirable to remove a fibrous portion of the diaper containing the fecal matter. In prior art diapers, this has been done by removing at least the entire facing layer necessitating minimal adherance between the facing layer and its adjacent elements to the detriment of proper functioning. According to the present invention, the fecal matter is removed by removing an exterior thickness portion of the facing layer by splitting it along a plane of weakness, making it possible to adhere the total marginal portion of the facing layer to the backing sheets over the entire interface between them.

Accordingly, the facing layer used in the diaper in one aspect of the present invention is formed by two half-thickness portions which are bonded together in laminar fashion to form a composite fabric. The outer half-thickness portion is formed of long fibers and short fibers at a given overall concentration, and in order to give this portion the proper feel and comfort characteristics, as well as draping, the outer face comprises a mixture of long and short fibers which is enriched with respect to long fibers in excess of the overall concentration. And, to minimize the cost, the inner face of the outer half-thickness portion comprises a mixture of long and short fibers enriched with respect to short fibers in excess of the overall concentration. Within the outer half-thickness portion, the concentrations of long and short fibers decrease gradually (i.e. there is no sharp interface between one concentration and another). The term "transition fabric" is used herein to refer to a fabric of the type just described.

The inner half-thickness portion is bonded to the short fiber-enriched face of the outer half-thickness portion and is characterized by an outer face, opposite the face bonded to the outer half-thickness portion, having greater structural stability than the short fiber-enriched face of the outer half-thickness portion. In this manner, the composite facing in the diaper of this embodiment is provided with outer faces having substantial structural integrity, and with a somewhat weakened interior portion comprised essentially of low cost short fibers. In a particularly preferred embodiment, the second half-thickness portion is similar to the first half-thickness portion and bonded thereto in mirror-like relationship. The process of forming the facing layer involves the use of a combination of techniques, such as shingling of fibers and controlled binder concentration which allows the facing fabric to be easily delaminated along the interior short fiber-enriched region.

The interior region, due to its low tensile strength (compared to the outer regions), may be torn along the central plane, or delaminated, so that the outer long fiber-enriched portion on which the fecal matter has been deposited may be separated from the remainder of the diaper. Since this outer layer is biodegradable, it may be, after being flushed down a conventional toilet, disposed of in sewage treatment facilities, thus overcoming any pollution problems and local regulations which have been promulgated to prohibit the disposal of fecal matter through public solid waste sanitation facilities. Moreover, since the facing layer is delaminated, the amount of fibrous diaper material that must be disposed of in the toilet is greatly reduced with a resultant decrease in the possibility of clogging.

Other embodiments discussed below utilize the basic delaminatable "sandwich" structure facing layer to provide a diaper with easy capability for disposing of fecal matter without disposal of a large amount of fibrous material.

As will be discussed in greater detail below, the present invention in its preferred embodiments is directed to a diaper in which the facing fabric has a transition fabric half-thickness portion which is improved by the addition of a second fabric having greater structural stability than the short fiber-enriched face of the transitional fabric so that the following advantages are obtained: (a) the facing layer has improved feel and strength characteristics at its outer face; (b) the tendency of the short fibers at the interior of the composite web to dust is minimized; (c) the overall production cost of the facing layer is reduced by utilization of the expensive long fibers in optimum distribution; (d) the inner face of the facing layer to be adhered to the backing sheet has sufficient structural stability so that it will not split or separate from the backing sheet; (e) the facing fabric is easily delaminated for the removal of fecal matter from the remainder of the diaper; and (f) the total amount of fibrous bulk which must be disposed of in a toilet bowl, and ultimately in a sewage treatment system is minimized.

although the composite facing layer fabric utilized in some embodiments of the present invention is described as being formed from two half-thickness portions, it should be understood that the term "half-thickness" does not necessarily mean that each portion is exactly the same thickness as the other or exactly 50 percent of the thickness of the composite fabric. The half-thickness portions can differ in their separate thicknesses, but when they do, the thinner portion should comprise at least 20 percent of the total thickness of the composite web.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective view, with certain portions broken away, of an open unfolded diaper in accordance with the present invention;

FIG. **2** is an enlarged partial cross section of the diaper of FIG. **1**, taken generally along line **2—2** in FIG. **1**;

FIG. **3** is a perspective view on a reduced scale of the diaper in its configuration after being put on an infant;

FIG. **4** is an enlarged partial cross section of the diaper facing layer, taken generally along line **4—4** in FIG. **5**; and

FIG. **5** is a simplified schematic view of the production line on which the diaper is made.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

While this invention is susceptible of embodiment in many different forms, there is shown in the drawings, and will herein be described in detail, a preferred embodiment of the invention and modifications thereof, with the understanding that the present disclosure is to be considered as an exemplification of the principles of the invention and is not intended to limit the invention to the embodiment illustrated. The scope of the invention will be pointed out in the appended claims.

Referring to the drawings and more particularly to FIGS. **1, 2** and **3,** the diaper assembly **10,** when fully opened and laid out flat, comprises a lowermost water-impervious backing sheet **12** which is rectangular in shape, a highly water-absorbent fibrous pad or batt **14,** which is also rectangular in shape, but smaller than the impervious sheet and centrally disposed thereon, and an overlapping facing layer **16** of fibrous material, which is also rectangular in shape and coterminous with the impervious sheet and in contact therewith in the marginal portions of the diaper extending peripherally beyond the absorbent batt, i.e., at the portions **16*b*** and **12*b*** of the facing layer **16** and impervious sheet **12,** respectively. The batt **14** has an integral, continuous, paper-like, densified highly compacted lowermost fibrous layer **18** which includes spaced, parallel, thickened densified portions **19** in the form of parallel lines that may extend completely through the cross-sectional thickness of the batt. Densified layer **18** is adhered to the impervious sheet **12** by bead lines **22** of adhesive substantially throughout the interface therebetween. Marginal portions **16*b*** and **12*b*** are also adhered to each other by bead lines **22** of adhesive.

In the preferred embodiment of the invention, moisture impervious sheet **12** is formed of polyethylene having a thickness of approximately 0.001 inch. The sheet may be smooth, or may be embossed to improve its drape and feel. Other suitable flexible moisture impervious sheets may be used in accordance with the invention, such as, for example, polyethylene terephthalate sheets having a thickness of about 0.0005 inch.

Batt **14** is formed of loosely compacted short cellulose fibers, such as wood pulp fibers, or cotton linters, held together by interfiber bonds requiring no added adhesive, as is known in the art. Briefly, this batt is a low bulk density coherent web of loosely compacted cellulose fibers preferably comminuted wood pulp fibers in the form of so-called "fluff."

The paper-like densified layer **18** of batt **14** is formed by a slight moistening of one surface of the batt followed by the application of pressure thereto. The nature of the batt and of its densified layer and the method of producing the same are described in U.S. Pat. No. 3,017,304, dated Jan. 16, 1962. The thickened densified portions **19** are formed by further compression of batt **14** while it is still moist, as will hereinafter appear.

The composite density of batt **14,** including its densified layer **18,** should be above about 0.07 gm./cc. and preferably between about 0.10 and 0.15 gm./cc. The foregoing density values are applicable to the diaper as produced. In storage and handling, the loft or thickness of the batt is increased to some extent, resulting in lowered densities.

Facing layer **16,** on an overall basis, is made of a given concentration of fibers consisting of short cellulosic fibers such as wood pulp fibers or cotton linters, in amounts of about 50 percent to about 98 percent, the balance being textile length fibers, such as fibers of rayon, polyester, cellulose acetate, nylon, etc.

Facing layer **16** is most preferably formed by joining two transistion fabrics **30** and **30'** (FIG. **4**). Since structural integrity is a prime consideration in the formation of the facing layer of the diaper of this invention, in any preferred embodiment of the present invention, a transition fabric is joined to the second fabric so that the transition fabric face enriched in long fibers is an outer face **15** of the facing layer. The inner face **15'** of the facing layer has greater structural stability than the en-

riched short fiber face of the transitional fabric so that it may be adhered to the impervious sheet **12** in the marginal areas.

Each half-thickness portion of the facing layer **16** is preferably formed by utilizing an air-laying process, such as, for example, the process disclosed in commonly assigned copending U.S. application Ser. No. 108,546, (now U.S. Pat. No. 3,768,118 dated Oct. 30, 1973) the disclosure of which is hereby incorporated by reference. This method produces two separate transition fabrics which are joined to form the facing layer, having opposed outer major faces **15** and **15'**, and central portion **17.** The transition zones between the faces **15** and **15'** and central portion **17** (formed by the inner faces **13** and **13'**) are characterized by decreasing concentrations of long fibers from the faces to the central portion of the product. Faces **15** and **15'** preferably are comprised of a greater amount by weight of long fibers and a lesser amount by weight of short cellulosic fibers (as compared with the overall concentrations of these fibers in each transition fabric) interspersed and blended therewith; with central portion **17** preferably being comprised of a greater amount by weight of short cellulosic fibers and a lesser amount by weight of textile length fibers (as compared to the overall concentrations of these fibers in each transition fabric) interspersed and blended therewith. It should be noted that while the central portion has been designated as element **17** for identification purposes, there is no sharp interface between it and faces **13** and **13'** since the composition changes are gradual.

Each transition fabric, on an overall basis, is made from a given overall concentration of short fibers, such as wood pulp fibers or cotton linters and a given overall concentration of long fibers, such as rayon, polyester, cellulose acetate, nylon, etc. The overall concentration of long fibers may be in varying percentages - in a range from 2 percent to 50 percent and preferably from 10 percent to 25 percent, with the remainder being made up by short fibers - for example, blends of 25 percent rayon fibers and 75 percent wood pulp fibers.

The amount of long fibers within the enriched face of the transition fabric is increased by at least 30 percent of its overall concentration while the long fibers are decreased by the same amount in the pulp enriched face. In the above mentioned example, having an overall concentration of 25 percent rayon fibers and 75 percent pulp fibers, an enrichment of at least 30 percent of long fibers means an increase of the long fiber concentration by at least 7.5 percent, or to a level of at least 32.5 percent on one face and an increase of the short fiber concentration by at least 7.5 percent, or to a level of at least 82.5 percent on the other face.

Facing layers suitable for use in this invention have fabric weights in the range of 1 to 5 oz/yd.^{2}, and most preferably within the range of 1.75 to about 2.75 oz-/yd.^{2} The present invention also contemplates that fabrics having an even lower fabric weight may be provided. After formation, the web is treated with a bonding agent, such as a self-cross-linking acrylic emulsion, and the facing web is treated with a wetting agent to partially counteract the water repellency of the bonding agent and bring the facing layer to the desired degree of wettability. One bonding agent which has been employed with considerable success is a latex of polyethylacrylate copolymer containing small amounts of acrylonitrile and a cross-linking monomer sold under the trademark HYCAR 2,600 × 120. The bonding agent should preferably be of the low viscosity type with a viscosity less than 5 centipoises. To avoid excessive water repellency, a surfactant, preferably a non-ionic surfactant, is included in the binder suspension. A non-ionic surfactant which has been found to be suitable is polyoxyethylene sorbitant monolaurate sold under the trademark TWEEN 20. In a typical application, the binder suspension is controlled to give the fabric a dry solids add on in the range of from about 4½ percent to 9 percent based on the fabric weight, of which from about 0.15 percent to about 0.30 percent is the amount of surfactant. In facing layers having an extremely low percentage of textile length fibers, such as in facing layers approaching 2 percent textile length fibers, the binder amount would be toward the high side of the above-mentioned range. It will be understood that the above mentioned surfactants moderate and reduce the water repellency which may be imparted to the short and long fibers of the web by the bonding agent which bonds them into an integral layer. After treatment with a wetting agent, the facing layer is receptive to penetration by urine but remains less wettable than the batt.

The diaper of this invention is normally packaged and sold in a folded condition as described in the Mesek et al. U.S. Pat. No. 3,612,055. Briefly, the side margins **12***b* and **16***b* of the impervious sheet **12** and the facing fabric **16,** together with a portion of batt **14,** are folded inwardly in a first fold to provide as the uppermost layer of the fold, a portion of the moisture impervious sheet. This sub-assembly is then folded outwardly along each edge in a second fold to cover the first folded portion and to expose the edge portion of the facing layer as the upper layer of the double fold. In the preferred embodiment, each double fold at the edge of the diaper comprises approximately ⅓ of the resulting transverse dimension of the folded diaper, leaving approximately ⅓ of the width of the folded diaper as a central unfolded and uncovered portion.

The diaper is held in its folded condition by two small central spots of adhesive applied between the main body of the diaper and the overlying sides **16***b* of the facing layer, one spot on each folded side of the diaper. When the diaper is to be put on the infant, the folds are opened on one side of each of the adhesive spots, and the open portion of the diaper is put under the infant's buttocks while the folded portion is raised into the crotch region. The final form of the diaper is shown in perspective on a reduced scale in FIG. **3.** In one form of the invention, as illustrated in FIG. **3,** the diaper is provided with adhesive tabs **26,** each having a fixed end secured to the impervious sheet **12** and a free end wherein the adhesive surface is covered with a facing sheet. The facing sheets are removed to expose the adhesive surfaces when the diaper is applied to the infant, as in the configuration shown in FIG. **3,** and the free ends of the adhesive tabs are secured to opposite corners of the diaper.

Suitable fibrous structures for making the pads or batts **14** used in this invention are made from short cellulosic fibers obtained by the grinding or comminution of compacted wood pulp fibers or cotton linters. The batts are initially formed by air blowing the cellulosic fibers onto a support at a total weight of about 2 to about 10 oz./yd.^{2}, and then subjecting the air blown fibers to heavy compression. The dense compacted paper-like layer or skin is prepared by moistening a sur-

face of the cellulosic batt with a fine spray of water, and then subjecting the moistened batt to pressure. The formation of the densified skin on the cellulosic batt is believed to be due to the formation of strong hydrogen bonds between contacting moistened fibers, similar to the bonds between the fibers in paper. By the proper selection of the amount of moisture applied to the surface of the batt and by the proper selection of degree of compression imposed, the properties of the densified skin may be varied as desired. The thickness, density, strength and other characteristics of the densified skin will depend upon the unformity by which the moisture is applied, the depth to which it penetrates, and the degree to which the fibers are compressed. For example, by finely spraying about 0.0015 cc. of water per square centimeter of web surface and then exposing the web to a pressure of about 40 lbs./in.^{2}, a suitable densified, coherent paper-like skin **18** is obtained on the surface of the web which has been moistened. The thickened densified portions **19** may be obtained by subjecting the web to additional pressure, as by the use of an embossing roll, while the web is still moist, and the additional pressure is preferably several times higher than the pressure that is applied to form the densified layer **18.**

The short fibers used in making batt **14** of this invention are generally entirely fibers of wood pulp or cotton linters. However, other cellulosic fibers may be used as well as blends of cellulose fibers with other fibers such as silk, wool, nylon and cellulose acetate. Highly purified kraft paper pulp fibers have proven to be most satisfactory for most applications.

The diaper of this invention may be assembled in equipment such as that schematically shown in FIG. **5.** A roll of short fibers **41** is provided to feed a source of short cellulosic fibers to grinding mill **42** from wbich a stream of fibers is blown onto belt **43** as a layer **44** weighing between about 2 and about 10 oz./yd.^{2}. The air blown layer is passed under compacting roll **46** from which it emerges with enough integrity to sustain itself as a web without the support of belt **43.** The web then passes through a pair of calender rolls **47** for further compression and then under nozzle **48** which deposits a fine spray of moisture on the upper surface of the web. The moistened web then passes between another set of calender rolls **49** which exert heavy pressure on it to form a skin **51** on its upper surface which will form the densified layer **18.**

The amount of moisture applied to the web may vary suitable from about 0.0005 to about 0.03 cc. of water per square centimeter of web surface, depending on the thickness of the paper-like densified skin desired, with lesser amounts of moisture being used for thinner webs and very thin, papery skins and greater amounts for thicker webs and skins of greater thickness.

The amount of pressure applied by rolls **49** may vary from about 5 to about 100 or more lbs./in.^{2}, with the commercially preferable range being from about 10 to about 50 lbs./in.^{2}. In a typical embodiment, the web is sprayed with about 0.0015 cc. of water per square centimeter of web surface and subjected to a pressure of about 40 lbs./in.^{2} to obtain a densified, coherent paper-like skin of uniform thickness on the surface of the web which has been moistened. The amount of moisture is selected so that the web is still moist following formation of the skin **51.** The web then passes between an embossing roll **52** and a back-up roll **53** for formation of the thickened densified portions **19.** Roll **52** has a plurality of axially spaced, circumferentially extending rib-like projections **54** that bear upon the previously formed skin **51,** and because of the residual moisture in the web and the increased pressure applied by projections **54,** thickened densified portions **19** are produced.

The pressure applied by the projections **54** on the embossing roll also produces recesses or air gaps **20** (FIG. **2**) in alignment with thickened portions **19.** As is evident from FIG. **2,** the unthickened portions of the densified layer **18** merge with the loosely compacted batt **14** at a generally planar interface **21,** and the thickened densified portions extend beyond interface **21** and into the loosely compacted batt **18** to give the absorbent panel a three dimensional strengthening effect.

After the skin and the thickened portions are formed, the absorbent web comes into contact with a web of facing material **16** and is supported thereby while being cut by cutter **56** into individual batts **14.**

Polyethylene film **12** is fed to the assembly from roll **58,** lines of adhesive being applied from applicator **59.** As described above, the adhesive is applied as parallel lines or beads between the impervious sheet and the densified layer of the batt (or the facing layer in the marginal portion of the diaper). Adhesive may, if desired, be applied as a continuous layer between the polyethylene and the batt, but such application tends to provide excessive stiffness. The adhesive may also be applied in other patterns, such as spaced dots or other forms of so-called "island" bonds, but fairly close overall adhesion between the sheet and the batt is required and no portion of the polyethylene should be more than about 2 inches from a point of adhesion. In the absence of such close overall adhesion, the polyethylene film may be separated from the densified layer to create substantial spaced in which uncontrollably large amounts of free liquid urine can accumulate.

After the facing material and polyethylene are brought into contact with opposite faces of the absorbent batts, the assembly is subjected to compression by rolls **60** and **61** to shape the diaper assembly, and the individual diapers are cut off by cutter **62.**

If desired, adhesive applicator **59** may be omitted and adhesion between the polyethylene layer and the fibrous layers may be achieved by heat sealing, employing a suitable sealing element in the production line.

As illustrated in FIG. **4,** the facing layer of this invention is formed by first air-laying two separate transition fabrics **30** and **30'** which are then placed in juxtaposition by a combining means **77** in the form of a roller over which the two fabrics are trained. After juxtapositioning, the webs are treated with a bonding agent, such as the above mentioned type.

Half-thickness portions **30** and **30'** of the facing layer **16,** as described above, are preferably formed in accordance with the process disclosed in the abovementioned application, Ser. No. 108,546. The half-thickness portions are prepared initially at positions **69** and **69',** which are similar in operation and correspondingly numbered. The half-thickness portions are prepared on process paths which are mirror images of one another so the fabrics being formed on each path are moving towards one another. During the description of operation, only one station will be described, but it will be understood that the description is equally applicable to the other or prime numbered station.

The half-thickness portion **30** is prepared by first feeding a supply of short cellulosic fibers **70** and a supply of textile length fibers **71** to a fiber opening and mixing apparatus, which takes the form of two individual oppositely rotating lickerins **74** and **75**, as described in the above-mentioned application. The fibers **70** and **71** are fed to the opening means **74** and **75**, respectively, at a desired rate to provide a web **30** with a desired overall fiber concentration. Lickerins **74** and **75** open the fibers from sources **70** and **71** and the fibers are suspended in separate gaseous streams which are impelled toward one another and combined to form a gaseous carrier stream. By adjusting baffle **68** which controls the amount of interaction between the air stream from lickerins **74** and **75**, to a position above the center line of the lickerins, the fibers from each separate stream will cross over one another. In this arrangement, the fibers from lickerin **75** tend to be deposited onto an upstream portion of the foraminous belt **90** and the fibers from lickerin **74** tend to be deposited further downstream on the previously deposited fibers from lickerin **75**. The deposited fibers are condensed on the belt **90** by suction box **91** which pulls air, as by suction fans, at a high velocity, through the belt **90** and deposited fibers. Half-thickness portion **30** is characterized by a major face **15** adjacent to belt **90** enriched in long fibers and a second major face **13** enriched in short fibers. And, the concentrations of long and short fibers decrease through the web **30** at greater distances from their enriched faces.

The webs **30** and **30'** emerging from apparatus **69** and **69'** are carried toward one another by conveyors **76** and **76'** to a combining apparatus **77** wherein the webs are placed in juxtaposition so that the combined web is characterized by outer faces **15** and **15'** enriched in long fibers.

The combined web is then carried by a conveyor **78**, to a bonding station where they may be through-bonded by a binding agent and surfactant of the types described above from source **79**. The left end roller of conveyor **78** is directly below and in line with combining roll **77** so that the combined web passes between the nip of roller **77** and the left end roller. The binder is deposited on one face of web from source **79** and the combined web then passes over a suction source **80** which draws the binder through the web and removes any excess binder solution.

The combined web from which facing layer **16** is to be cut is then dried by passing through drying station **81**. Preferably, the drying station is in two stages: (a) a first stage which is designed to promote a drying action throughout the depth of the combined web and is illustrated schematically by a box designated as **82**; and (b) a second stage which is designated to apply heat to the exterior surface of the web and is illustrated by a series of alternatingly rotating steam cans **83** and **84**.

In the drying of a web by application of heat to the web surfaces, there is a tendency for the binder solution to migrate towards the heat source as the water carrier is evaporated. Reliance on surface heating as the sole means of drying may cause sufficient binder migration to adversely affect the strength of the interior of the composite web. It is therefore preferred that a portion of the heating action be carried out in a manner which makes heat available at the interior of the web, such as dielectric heating, infra-red heating, or heating by a strong current of hot air which brings heat to the interior of the web by convection.

The relative proportions of evaporation achieved in the first and second stages will depend upon the balance of properties desired in the final fabric. It is desired to have sufficient migration to the major surfaces to provide the desired strength and abrasion resistance at the surfaces and to weaken the center of the fabric sufficiently to make it easy to delaminate the fabric by tearing. It is not desired to weaken the center of the fabric to such an extent that delamination can occur during normal use of the fabric in a diaper facing.

After the drying process is completed, the final web is brought into contact with the absorbent batt material by roller **85**.

For some applications, it may be desirable to through-bond each half-thickness portion web separately and then bond them together. To this end, binder stations, similar to that described, would be positioned relative to conveyors **30** and **30'** which would, of course, be foraminous belts. With this type of apparatus, the binder station described would be removed and a bonding applicator could be positioned between webs **30** and **30'** above the combining apparatus **77** to deposit bonding at their interface.

As discussed above, the second half-thickness portion web may be of a variety of types so long as the outer face (opposite the face which is bonded to the pulp benriched face of the first half-thickness portion web) is of greater structural integrity than the pulp-enriched face of the transition web.

While the preferred embodiment utilizes two juxtaposed transition fabrics **30** and **30'**, it should be noted that the transition fabrics may be different as to the nature of the long or short fibers used, the overall concentrations, the thicknesses, or the amount of enrichment at each face.

For some uses, it may be advantageous to use different long fibers in the half-thickness portions because of the difference exposure of the opposite sides of the composite web and the different requirements at each side. For example, the outer face **15** (intended to cone into contact with the baby's skin) can be rich in long fibers of rayon which provides the desired strength in combination with a smooth feel. The opposite face which is in the interior of the diaper, where feel is not important, can be rich in long fibers of water-insoluble polyvinyl alcohol, which, despite its harsher feel, can be used to provide the desired strength more effectively because of its excellent bonding properties. Alternatively, the fabric can be rich in long polyester fibers on its outer face to provide superior smoothness and rich in a less expensive long fiber on its opposite face.

The diaper produced by the apparatus of FIG. **5** is particularly useful for delamination and disposal of fecal matter since the individualized fibers of the facing layer are deposited on the foraminous belts **90** and **90'** in a shingle-like manner in the longitudinal direction of the webs. This shingling effect, as described in Mesek, U.S. Pat. No. 3,483,051, produces a facing layer which resists splitting in one direction (opposite the shingling) but which may be uniformly split in the shingling direction.

After the infant has excreted fecal matter on the diaper, the diaper is removed in the usual manner following the disengagement of the adhesive tabs **26** from each side of the impervious sheet **12**. The diaper is then

positioned on a flat surface or over a toilet with the fingers of one hand grasping an edge of the outer portion **15** and those of the other hand grasping the impervious backing sheet **12.** The facing layer is then pulled so that the outer portion **15** separates or delaminates along the central plane due to the low tensile strength of the interior portion enriched in short fibers. After the outer portion has begun to separate at an edge, this separation is then grasped and the outer portion is delaminated from the inner portion of the facing layer and remainder of the diaper structure. Since the outer portion **15** is characterized by a higher concentration of long fibers, it is of ample strength to support any fecal matter that has been deposited thereon and may be folded up and deposited in the toilet to be flushed away. The remaining portion of the diaper structure including the impervious sheet, batt, and remaining portion of the facing layer is disposed of by placing them in a suitable receptacle. In this manner, only a small amount of fibrous material must be flushed away and clogging problems are greatly reduced.

In making the diaper of this invention by the method of FIG. **5,** belts **90** and **90'** move toward each other and the half-thickness portions formed thereon are joined together at their exposed surfaces, i.e., the surfaces that are rich in short fibers. If desired, however, belt **90'** can be arranged to move in the same direction as belt **90** and to have fiber source **70'** and **71'** reversed in position with respect to the belt movement so that the short fibers are primarily deposited upstream and are enriched in the face in contact with the belt. In this case, the web formed in belt **90'** would be taken off the belt and transposed onto the top of the web produced on belt **90** so that the short fiber-rich surface originally in contact with belt **90'** comes into contact with the short fiber-rich exposed surface of the web on belt **90.**

The facing layer of this invention can also be manufactured on a single belt, rather than on a pair of belts such as belts **90** and **90'.** Fiber sources **70'** and **71',** together with lickerins **74'** and **75'** and baffle **68'** may be transposed to overlie belt **90** at a location downstream of the comparable elements **70, 71, 74, 75** and **68.** In this case, a stream rich in long fibers crossed over from lickerins **75** would be deposited first, a stream rich in short fibers crossed over from lickering **74** would be deposited second, a stream rich in short fibers crossed over from lickerin **74'** would be deposited third, and a stream rich in long fibers crossed over from lickerin **75'** would be deposited fourth.

A further method of producing a sandwich-like facing layer of long - short - long fibers which may also be delaminated along the short fiber layer to dispose of fecal matter utilizes a single foraminous belt similar to belt **90** on which three single lickerins would be positioned. In this method, the first lickerin deposits a layer of long fibers; the second lickering then deposits short fibers further downstream and then a layer of long fibers is deposited on the short fiber layer still further downstream. This sandwich-like web is then directed to a binder station and drying station, as discussed above; and the web then enters the diaper production stream at the position of roller **85** in FIG. **5.**

In the preparation of the foregoing sandwich-like web, the lickerins may, if desired, be placed close together and arranged to deposit fibers at closely spaced locations so that some intermixture will occur, providing some short fibers in the long fiber-rich outer sections and some long fibers in the short fiber-rich center section. There should, however, be a definite distinction in the concentrations of short and long fibers as between the central portion of the web and the opposite faces, just as in the webs made by the juxtaposition of separate web half-thicknesses. Preferably, the concentration of long fibers in each of the outermost 25 percent sections of thickness is at least 1.5 times the concentration of long fibers in the central 50 percent section of thickness and most preferably at least two times said concentration.

Additional alternate embodiments of the present invention facing layers may be employed which utilize a single transition fabric which is joined at its short fiber-enriched face to a second half-thickness portin, having greater structural stability than the pulp-enriched face of the transition fabric. Among the alternate second half-thickness portions of particular interest are: any one of (**1**) a web of uniform blended composition throughout its thickness, or either of two different forms of webs of non-uniform composition throughout their thickness, namely (**2**) a web having one outer face made of short fibers, the other outer face made of long fibers and an intermediate layer that is a uniform blend of short and long fibers, or (**3**) a web of two layers of fibers, one short and one long, with the layers being interlaced only at their interface.

When the variations (**2**) and (**3**) are utilized as the second half-thickness portion to be joined to the pulp-enriched face of the transition fabric to make the facing layer, it is the short fiber face of the second half-thickness portion that is joined to the transition fabric so that the face with the longer fibers remains an outer face in the composite.

In addition to the above products which can be used as the second half-thickness portion, the invention also contemplates (**4**) a thin layer made entirely of long fibers. The last-named embodiment is not ordinarily preferred because of its expense.

It will be understood by those skilled in the art that variations and modifications of the specific embodiments described above may be employed without departing from the scope of the invention as defined in the appended claims.

What is claimed is:

1. A multi-layer diaper comprising: a porous laminated facing layer to be brought into contact with the infant's skin, said facing layer including two juxtaposed through-bonded nonwoven half-thickness portions, each half-thickness portion having one major face facing outwardly in said facing layer, a first of said nonwoven half-thickness portions being characterized by a given overall concentration of long fibers and short fibers, said first half-thickness portion having long fibers in excess of said given overall concentration at said major face facing outwardly in said facing layer, having short fibers in excess of said given overall concentration at the opposite major face, and having a transition of fiber concentrations between said major faces, and the second of said half-thickness portions being bonded to said first half-thickness portion at said face wherein the concentration of short fibers is in excess of said given overall concentration, said second half-thickness portion having at its major face, which faces outwardly in said facing layer, greater structural integrity than said bonded face of said first half-thickness portion; a

highly porous, loosely compacted cellulosic batt in face-to-face juxtaposition with the outer face of said second half-thickness portion; and a water-impervious backing sheet adhered to the surface of said batt opposite said facing layer.

2. A diaper as set forth in claim **1** wherein said facing layer and water-impervious backing sheet are coterminous; said batt being smaller in dimension than said facing layer and backing sheet and centrally disposed therebetween; and the marginal portions of said facing layer and backing sheet extending beyond said batt being adhered to one another.

3. A diaper as set forth in claim **1** wherein said second half-thickness portion comprises a non-woven material having at its outer face, a concentration of long fibers in excess of the concentration of long fibers at said bonded face of said first half-thickness portion.

4. A diaper as set forth in claim **1** wherein said second half-thickness portion is characterized by a given overall concentration of long and short fibers, said second half-thickness portion having long fibers in excess of said overall concentration at said major face and having short fibers in excess of said given overall concentration at the other face, and having a transition of fiber concentrations between said faces.

5. A diaper as set forth in claim **4** wherein the long fibers of said first and second half-thickness portions are different from each other.

6. A diaper as set forth in claim **4** wherein the long fibers of said first and second half-thickness portions are of the same fiber material.

7. A diaper as set forth in claim **4** wherein the short fibers of said first and second half-thickness portions are of the same fiber material.

8. A diaper as set forth in claim **4** wherein the short fibers of said first and second half-thickness portions are different from each other.

9. A diaper as set forth in claim **4** wherein the given overall concentrations of long and short fibers in said first and second half-thickness portions are the same.

10. A diaper as set forth in claim **4** wherein the given overall concentrations of long and short fibers in said first and second half-thickness portions are different.

11. A diaper as set forth in claim **4** wherein the concentrations of long and short fibers at the faces of said first and second half-thickness portions wherein said concentrations are in excess of the given overall concentration for each half-thickness portion are the same.

12. A diaper as set forth in claim **4** wherein the concentrations of long and short fibers at the faces of said first and second half-thickness portions wherein said concentrations are in excess of the given overall concentration for each half-thickness portion are different.

13. A diaper as set forth in claim **4** wherein said first and second half-thickness portions are of equal thickness.

14. A diaper as set forth in claim **4** wherein said first and second half-thickness portions are of different thicknesses.

15. A multi-layer diaper comprising: a porous facing layer to be brought in contact with the infant's skin, said facing layer including an internal region of predominantly short fibers and external regions on opposite faces thereof having a greater proportion of long fibers than said internal region; a highly porous absorbent pad, smaller in area than said facing layer, in face-to-face juxtaposition with one face of said facing layer; and a water-impervious backing sheet coterminous with said facing layer adhered to the surface of said pad opposite said facing layer and to the marginal portions of said facing layer extending beyond said pad.

16. A diaper as set forth in claim **15** wherein said facing layer is comprised of a given overall concentration of long fibers of regenerated cellulose and short fibers of natural cellulose, said facing layer having a mixture of fibers throughout its thickness, said mixture varying from a minimum concentration of said long fibers at a mid-thickness portion of said facing layer to maximum concentration of long fibers at opposite major faces of said facing layer with transitions of fiber concentrations at increasing distances from said mid-thickness portion to said major faces.

17. A diaper as set forth in claim **16** wherein said maximum concentrations of long fibers at opposite major faces of said facing layer are identical concentrations.

18. A diaper as set forth in claim **16** wherein said facing layer is through-bonded with a binder material which imparts to said facing layer a decreased wettability as compared to a facing layer of unbonded fibers.

19. A diaper as set forth in claim **16** wherein said pad is a highly porous, loosely compacted cellulosic batt.

20. A multi-layer diaper comprising: a porous facing layer to be brought in contact with the infant's skin, said facing layer including an internal region of predominantly short fibers and external regions on opposite faces thereof having a greater proportion of long fibers than said internal region; a highly porous absorbent pad in face-to-face juxtaposition with one face of said facing layer; and a water-impervious backing sheet adhered to the surface of said pad opposite said facing layer.

21. The multi-layer diaper of claim **20** wherein the concentration of long fibers in each 25 percent outer thickness portion of said facing layer is at least **1.5** times as high as the concentration of long fibers in the central 50 percent thickness portion.

22. A method of disposing of fecal matter from a diaper worn by an infant, said diaper having a delaminatable facing adjacent the infant's skin and covering an absorbent batt on the opposite side thereof, said method comprising the steps of: removing said diaper after the infant has excreted fecal matter thereon, delaminating one layer of said facing layer along an internal zone of weakness in the interior thereof while leaving another layer in place covering said batt, thereby separating the fecal material on an outer thickness portion of said facing layer from the remaining portion of the diaper, and disposing of said fecal matter and said portion of said facing layer separately from the remainder of the diaper.

23. A method as set forth in claim **22** wherein said facing layer is formed with two nonwoven fibrous half-thickness portions; the fibers in each half-thickness portion being arranged in overlapping shingle orientation and the shingle orientation of each half-thickness portion being opposite, and said delaminating step is performed by splitting the facing layer along the shingle interface.

24. A method as set forth in claim **22** wherein said facing layer is comprised of long and short fibers, with a predominance of short fibers at the midportion of said facing layer; and said delaminating step is performed by splitting the facing layer along said predominately short fiber midportion.

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