April 27, 1965 F. H. SEXSMITH 3,180,775

METHOD OF MAKING NON-WOVEN FABRICS

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Fig. 1.

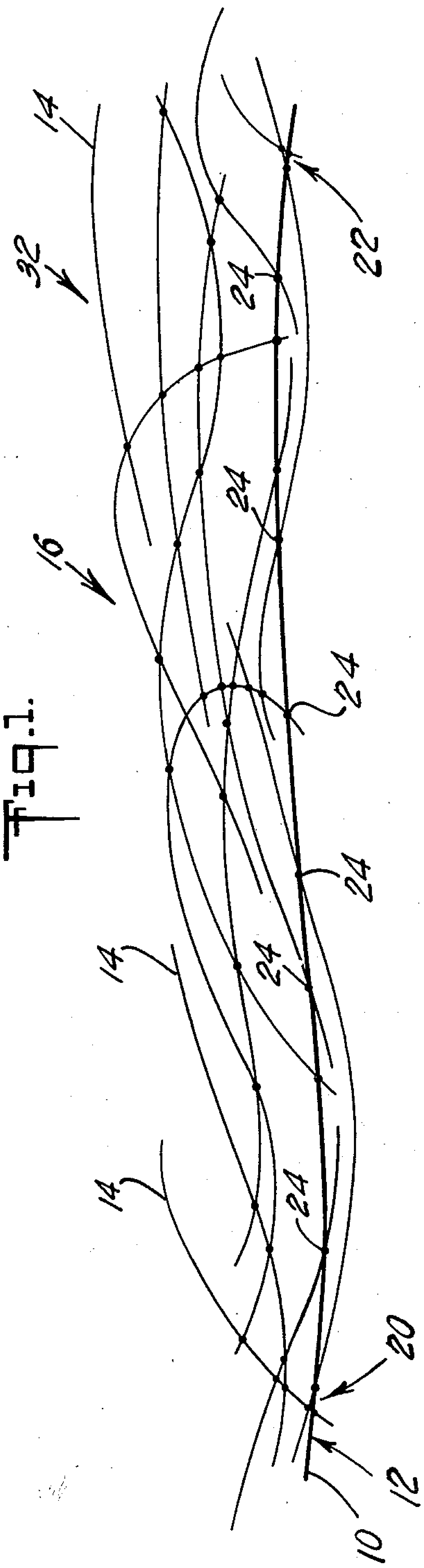

Fig. 2.

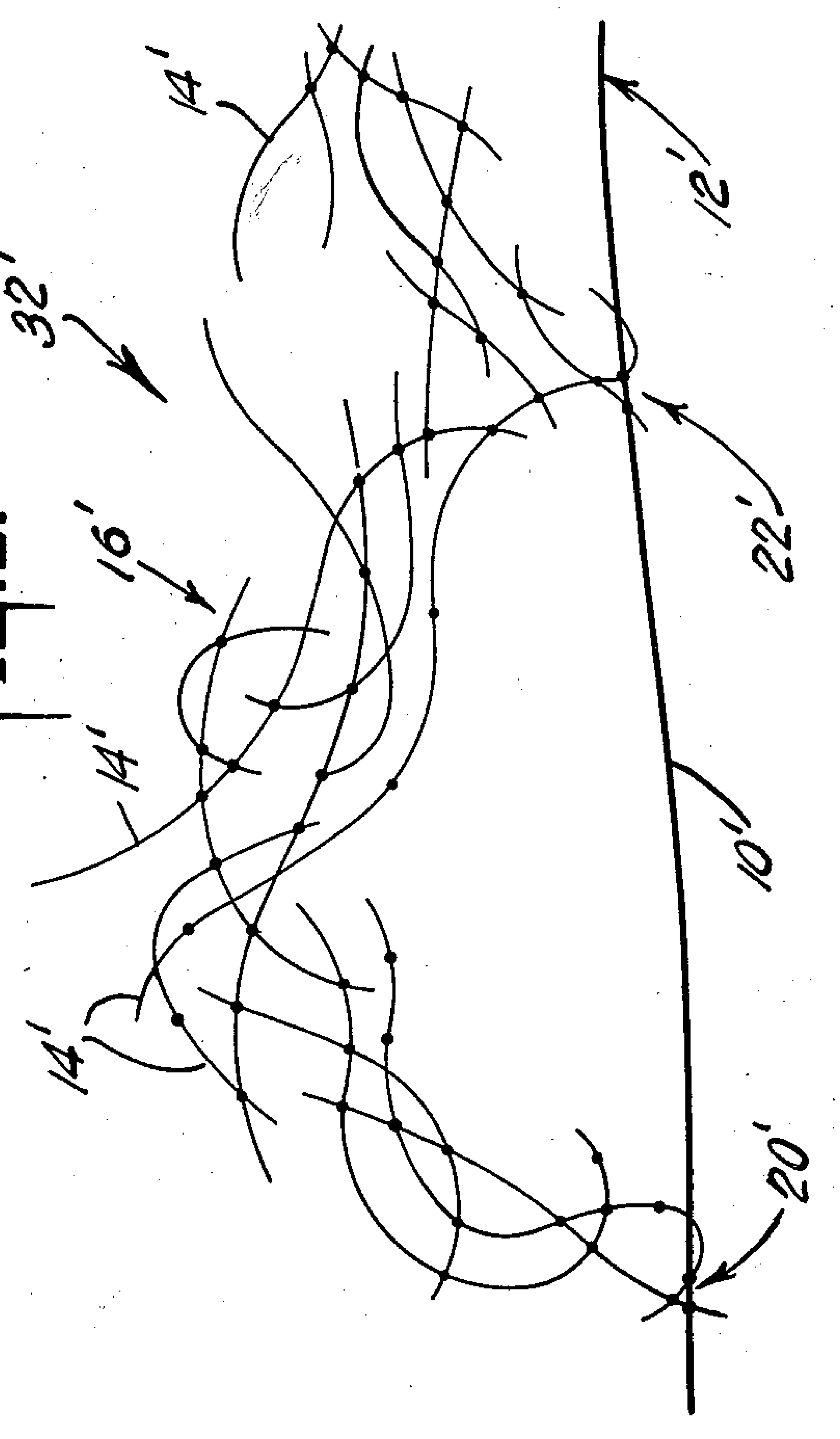

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Fig. 3.

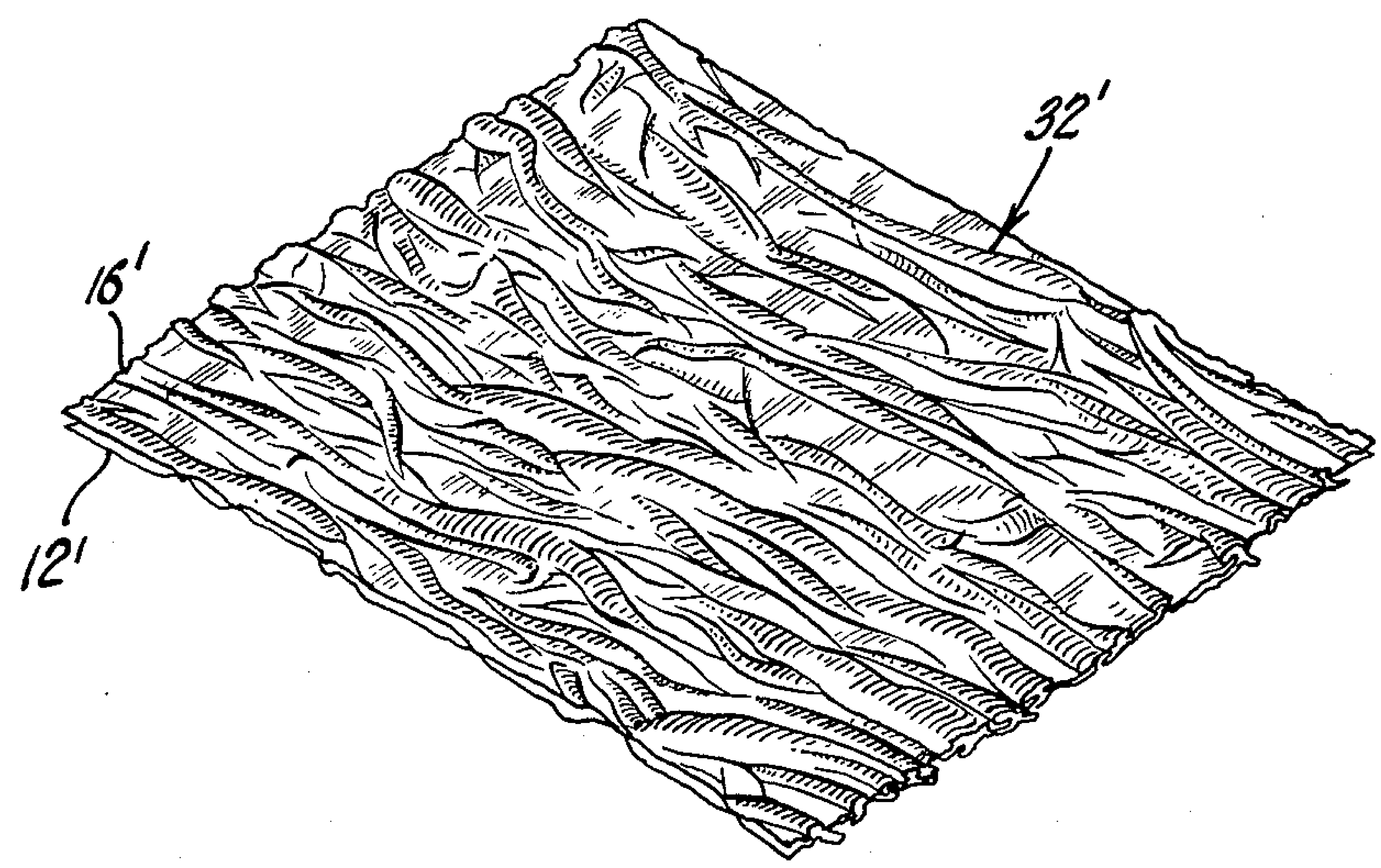
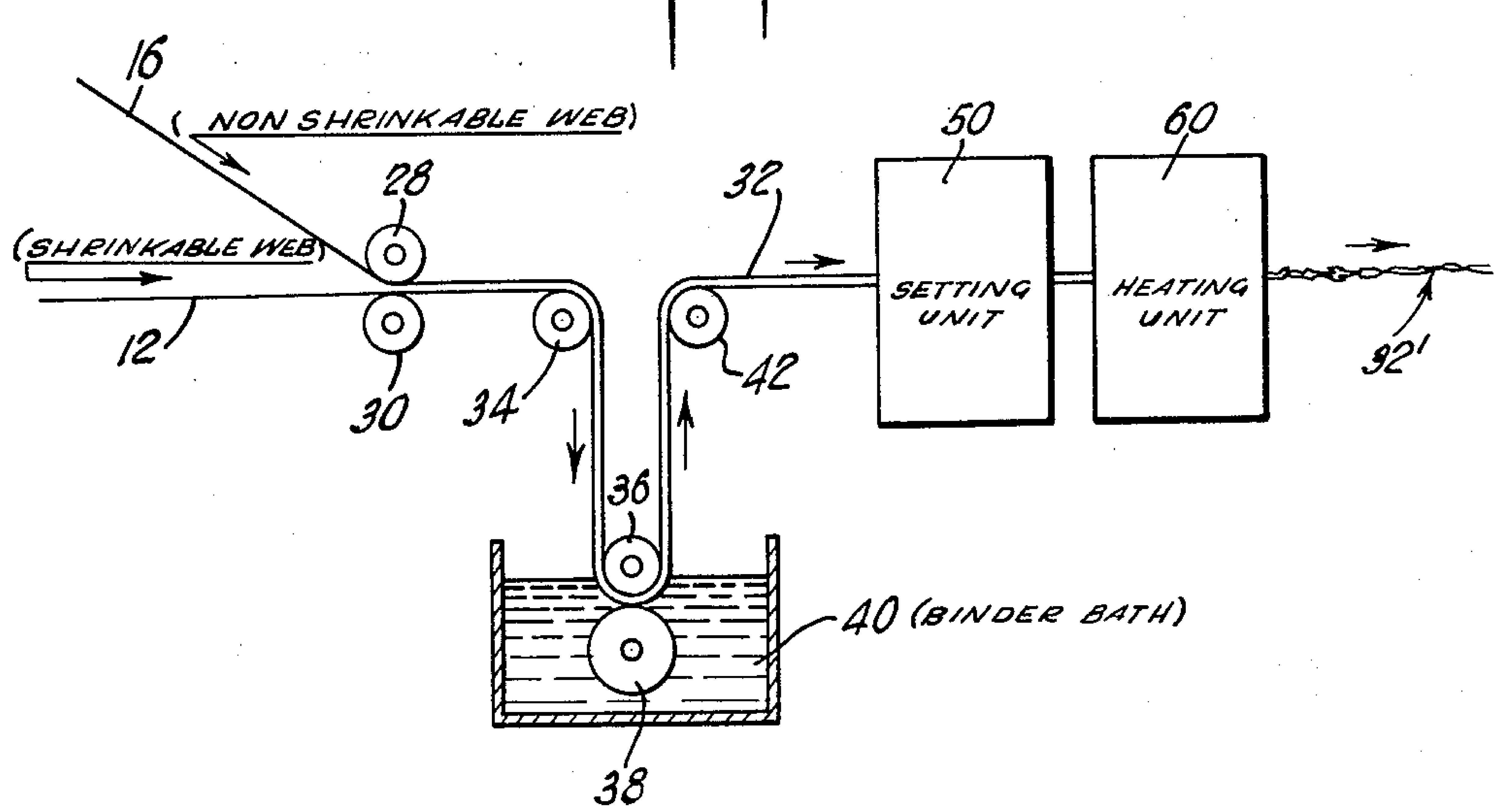


Fig. 4.



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METHOD OF MAKING NON-WOVEN FABRICS

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The present invention relates to textile fabrics having a lofty, bulky appearance and unique surface interest and to methods of making the same. More particularly, the present invention is concerned with so-called "nonwoven" textile fabrics, i.e., fabrics produced directly from textile fibers without the use of conventional spinning, weaving or knitting operations, and to methods of creating unusual three-dimensional effects in such nonwoven textile fabrics.

Although not limited thereto, the invention is of primary importance in connection with nonwoven fabrics formed from card webs of textile fibers, the major proportion of such textile fibers being oriented predominantly in one direction. Typical of such nonwoven fabrics are the so-called "Masslinn" nonwoven fabrics, some of which are described in greater particularity in U.S. Patents 2,705,687 and 2,705,688, which issued April 5, 1955, to De Witt R. Petterson et al. and Irving S. Ness et al., respectively.

Another aspect of the present invention is its application to nonwoven fabrics wherein the fibers are basically predominantly oriented in one direction but are also reorganized and rearranged in predetermined designs and patterns of fabric openings and fiber bundles. Typical of such nonwoven fabrics are the so-called "Keybak" bundled fabrics, some of which may be produced by methods and with apparatus more particularly described in U.S. Patent 2,862,251, which issued December 2, 1958, to Frank Kalwaites.

Still another aspect of the present invention is its application to nonwoven fabrics wherein the fibers are disposed at random and are not predominantly oriented in any one direction. Typical of such nonwoven fabrics are the so-called "Isotropic" nonwoven fabrics, some of which may be produced by methods and with apparatus more particularly described in U.S. Patents 2,676,363 and 2,676,364 which issued April 27, 1954, to Charles H. Plummer. Other examples of typical nonwoven fabrics wherein the fibers are not predominantly oriented in any one direction are those made by modified papermaking techniques.

Nonwoven fabrics made by any of the above-described methods and apparatus have become increasingly important in the textile and related industries, primarily because of their low cost of manufacture for a given coverage, as compared to the cost of more conventional textile fabrics made by spinning, weaving and knitting operations. Examples of uses for such nonwoven fabrics are wrapping and packaging materials, surgical dressings and bandages, covers or other components of sanitary napkins, hospital caps, dental bibs, eye pads, dress shields, diapers and diaper liners, casket liners, wash cloths, hand and face towels, handkerchiefs, table cloths and napkins, curtains and draperies, quilting or padding, cleaning materials, shoe shine cloths, battery separators, air or other filters, etc. Because of this wide variety of uses, these nonwoven fabrics are available commercially in a wide range of fabric weights of from as little as about 140 grains per square yard to as much as about 2400 or more grains per square yard.

Fabric stability and strength are usually created in such nonwoven fabrics by bonding with adhesive or cementitious materials. The bonding operation employed for stabilizing and strengthening nonwoven fabrics has taken on many forms, one popular form being the intermittent

bonding of the nonwoven fabric with a predetermined pattern of spaced discrete binder areas or lines extending across the width of the nonwoven fabric.

Methods of creating unusual three-dimensional effects in such intermittently bonded nonwoven fabrics are disclosed and claimed in co-pending, commonly-assigned patent application, Serial Number 31,450, filed May 24, 1960, now abandoned. In that application, it was indicated that the total surface coverage of the binder areas or lines should preferably not substantially exceed about 35% of the total surface of the nonwoven fabric in order to obtain certain desired predetermined three-dimensional effects. It was also stated therein that there should be clear interbinder spaces or relatively unbonded areas between the binder areas so that fibers are provided therein which are free to buckle or puff to create a rippled effect.

It has now been discovered that three-dimensional nonwoven fabrics may be produced having a novel appearance and unique surface interest, along with increased bulk and loft, as well as a full and soft hand, with binder coverages which substantially exceed about 35% of the total surface of the nonwoven fabrics, even up to over-all bonding, that is, 100% binder coverage. Such nonwoven fabrics are not thin, flat or drab and do not have a harsh or papery feel.

Such improved nonwoven fabrics may be produced by assembling a plurality of fibrous webs, at least one web comprising relatively shrinkable fibers and at least one other web comprising relatively non-shrinkable fibers, bonding the plurality of fibrous webs together by means of an over-all bonding process, for example, and then exposing the plurality of webs to a treatment sufficient to shrink the shrinkable fibers but not to materially affect the non-shrinkable fibers. In this way, the fibrous web comprising the shrinkable fibers contracts to a fraction of its original size and causes the fibrous web comprising the non-shrinkable fibers to become puffed and distended and to extend away from the plane of the shrunken fibrous web in the form of pillows, ripples, etc., which, however, do not appear to have any predetermined patterned effect, but which do have a somewhat regular effect, when considered in gross.

The precise chemical and/or physical mechanism, whereby such pillows and ripples appear on the surface of the over-all-bonded nonwoven fabric, is not understood completely. However, it is believed that such effects are accomplished in the following manner which will be described with reference to the accompanying drawings. Such description and drawings are primarily for illustrative purposes only and are offered as a reasonable explanation of the inventive concept but are not intended to limit the invention in any way.

In the drawings:

FIG. 1 is an idealized, fragmentary cross-sectional view, showing individual fibers of a portion of a nonwoven fabric composed of a plurality of fibrous webs, prior to processing in accordance with the principles of the present invention;

FIG. 2 is an idealized, fragmentary cross-sectional view, showing individual fibers of a portion of a nonwoven fabric composed of a plurality of fibrous webs, after processing in accordance with the principles of the present invention;

FIG. 3 is a schematic, fragmentary perspective view of a portion of a nonwoven fabric composed of a plurality of fibrous webs, after processing in accordance with the principles of the present invention; and

FIG. 4 is a schematic view of apparatus and method suitable for utilizing the principles of the present invention on a plurality of fibrous webs.

As shown in FIG. 1, a two-layered fibrous structure

32 comprising a lower shrinkable layer 12 and an upper non-shrinkable layer 16 is used to illustrate the invention and, in order to simplify the description thereof, only one shrinkable fiber 10 of the lower shrinkable layer 12 is shown which, as a result of the over-all bonding process, is bonded to several non-shinkable fibers 14 of the upper non-shrinkable layer 16. It is to be appreciated, however, that there are very many more fibers in the lower shrinkable layer 10 as well as very many more fibers in the upper non-shrinkable layer 16 and that the action described herein is repeated many times over throughout the entire interfacial surface of the two-layered fibrous structure 32. The shrinkable fiber 10 is bonded to several non-shrinkable fibers 14 by means of spaced bonds 20, 22 and a number of intermediate bonds 24 located between bonds 20 and 22. The exact number of bonds cannot be determined accurately but it is to be appreciated that there are a very large number of such bonds in the two-layered fibrous structure 32.

The two-layered fibrous structure 32 of FIG. 1 is then exposed to a shrinking treatment, such as disclosed in greater detail in co-pending patent application Serial Number 31,450, filed May 24, 1960. The shrinkable fibers 10 decrease in length and assume configurations such as shown in FIG. 2 by the shrunken fibers 10' of the shrunken layer 12'. In so shrinking, the distance between original bonds 20 and 22 (shown as final bonds 20' and 22' in FIG. 2) decreases. During this shrinking process the bonds intermediate between bonds 20' and 22' are ruptured, causing the non-shrinkable fibers 14' of the non-shrinkable layer 16' to extend away from the shrunken layer 12', as illustrated in FIG. 2. It cannot be predicted previously to the shrinking treatment which bonds are the strongest and consequently the precise bonds which are or are not ruptured cannot be determined before the shrinking treatment. As a result, the bonds which remain unruptured are scattered here and there throughout the resulting nonwoven fabric 32' and, as a result, the pillows and ripples which appear as a result of the shrinking treatment are irregular and do not possess any periodically recurring or predetermined pattern.

The resulting rippled nonwoven fabric 32' having such a random or haphazard arrangement of its three-dimensional effects is illustrated in FIG. 3 and it is to be noted that the pillows and ripples do not have any predetermined repetitive arrangement. The intensity of the effect realized is, of course, dependent upon the nature or extent of the shrinking treatment applied to the nonwoven fabric.

The particular treatment employed to cause the shrinkable fibers to contract may be chemical and/or physical in nature. Although many methods involving the use of chemical shrinking agents are possible, the preferred treatment is a simple heating method which develops the potential shrinkable properties of fibers and such treatment will be used to describe the present invention. It is to be pointed out, however, that the use of such heat-shrinkable fibers rather than chemical-shrinkable fibers is merely illustrative and that such is not to be construed as limitative of the broader aspects of the present invention.

The fibers of the heat-shrinkable web may be selected from a large group of fibers having such heat-shrinkable properties. Representative of such fibers are the vinyl polymer fibers, notably "Vinyon," a vinyl chloride-vinyl acetate copolymer composed of at least 85% and usually up to 90% by weight of vinyl chloride; "Rhovyl," a polyvinyl chloride copolymer; saran, a polyvinylidene chloride-vinyl chloride copolymer composed usually of from about 4% to about 15% by weight of vinyl chloride; polyesters such as "Dacron" and "Kodel"; polyolefins such as low, medium and high density polyethylenes, isotactic polypropylenes; acrylics and modacrylics such as "Dynel," "Verel," "Acrilan," etc.

Although a few representative heat-shrinkable fibers have been disclosed, it is to be appreciated that the inventive concept in its broader aspects is not to be construed as limited thereto. Substantially any synthetic thermoplastic fiber may be so manufactured or processed as to possess some shrinkage capabilities and consequently substantially any synthetic fiber may potentially be applicable to the principles herein disclosed. The greater the shrinkage, the greater is the potential application. As an indication of the degree of shrinkage involved, it can be stated that "Rhovyl" exhibits shrinkages up to about 55%; "Verel" up to about 48%; "Dacron" up to about 45%; and "Dynel" up to about 50%. Other fibers containing greater or lesser percentage shrinkages are, of course, useful where such greater or lesser effects are desired. In the main, however, percentage shrinkages of from about 15% to 65% has been found satisfactory with a range of from 30% to about 65% being preferred. It is to be noted that the fibers must be in a relaxed condition during the shrinking process so that they be permitted to contract freely, as desired, to the maximum percentage or to any required percentage of shrinkage.

The non-heat-shrinkable fibers may be selected from a large group of fibers which are relatively non-heat-shrinkable with respect to the heat-shrinkable fibers.

Representative of such non-heat-shrinkable fibers are the natural fibers, notably cotton and linen, or the synthetic fibers, notably the cellulosics such as regenerated cellulose made by the viscose or cuprammonium process, cellulose esters such as the acetate and triacetate; polyamides such as nylon 6/6, nylon 6, nylon 11, etc.; fluorocarbons such as "Teflon"; mineral fibers such as glass; etc.

Inasmuch as the three-dimensional effect is obtained by means of the difference in heat-shrinking properties, it is possible to obtain such an effect by using two heat-shrinkable fibers, provided the difference in heat-shrinking properties is sufficient, or if the heat-shrinkable properties of one may be developed without developing the heat-shrinkable properties of the other. The important factor to be considered, therefore, is the differential in shrinking which is developed under the conditions to which the webs are exposed during the heat treatment.

It is not essential that each fibrous web be composed of only one type of fiber. Blends and mixtures are, of course, possible. However, it must be remembered that the blends or mixtures of fibers be such that the desired heat-shrinkable properties be developed. For example, in the case of the heat-shrinkable web, per se, it has been found that as little as about 15% by weight of heat-shrinkable fibers may be present therein and still develop sufficient heat shrinkability.

The percentage of the heat-shrinkable fibers with respect to the total weight of all the webs in the nonwoven fabric is also a factor to be considered to insure the development of the desired surface effects. As little as about 5% by weight of the heat-shrinkable fibers has been found satisfactory; from about 16% to about 50% by weight is found preferable. Greater than 50% by weight may be used where special effects are desired.

It is preferred that the fibers be of staple or equivalent length, or at least cardable, that is to say, from about ½ inch in length up to about 3 inches or more in length. Shorter fibers, such as woodpulp fibers, cotton linters, asbestos fibers, and the like may be added in various proportions to comprise about 50% by weight of the heat-shrinkable web, or even may comprise the entire non-heat-shrinkable web, particularly where the original method of web formation involves a fluid deposition of fibers, such as in a papermaking process, or in air deposition techniques.

The denier of the synthetic fibers used in forming the webs is preferably in the range of the approximate thickness of the natural fibers mentioned and consequently deniers in the range of from about 1 to about 3 are preferred. However, where greater opacity or greater covering power is desired, deniers of down to about ¾ or even about ½ may be employed. Where desired, deniers of up to 10, 15 or higher, may be used. The minimum and maximum denier are, of course, dictated by the desires or requirements for producing a particular web or nonwoven fabric, and by the machines and methods for producing the same.

The weight of the individual fibrous web or layer of starting material may be varied within relatively wide limits, depending upon the requirements of the finished product. A single, thin web of fibers, such as produced by a card, may have a weight of from about 40 to about 200 grains per square yard. This minimum weight of nonwoven fabric contemplated by the present invention is, however, about 120 grains per square yard, obtained by plying three webs. The maximum weight may range upwards to about 2500 or more grains per square yard. Within the more commercial aspects of the present invention, however, web weights of from about 140 grains per square yard to about 2400 grains per square yard are contemplated.

The number of layers of webs in the starting materials must, of course, be at least two, in order to obtain the desired or required effects. Three, four, five or more layers in any desired arrangement may be used where special effects are desired.

The binder used in adhering the plurality of webs together may be selected from a large group of such binders known to industry. It is necessary, however, that a binder be used which can satisfactorily adhere to and bond the different types of fibers together. Representative of the binders available for such a purpose are: regenerated cellulose; vinyl resins such as polyvinyl acetate, polyvinyl acetal, polyvinyl chloride, polyvinyl alcohol, etc., either as homopolymers or copolymers; acrylic resins such as ethyl acrylate, methyl methacrylate, ethyl acrylate, butyl methacrylate, etc.; polyalkylene resins such as polyethylene, polypropylene, etc.; butadiene resins such as butadiene-acrylonitrile, butadiene-styrene, etc.; urea resins such as urea-formaldehyde, cyclic urea-formaldehyde, etc.; aldehyde resins such as melamine-formaldehyde, phenol-formaldehyde, resorcinol-formaldehyde, etc.; epoxy resins; cellulose derivatives such as carboxymethyl cellulose; hydroxyethyl cellulose, etc.; starches; gums; casein; etc.

The percent add-on of such binder material may be varied within relatively wide limits, depending to a large extent upon the specific binder employed and upon the type, weight and thickness of the nonwoven fabric. For some binders, as low as about 2% by weight up to about 15% by weight, based on the weight of the dry webs being bonded, has been found satisfactory. For other binders, as high as from about 20% to about 65% by weight has been found preferable. Within the more commercial aspects of the present invention, however, from about 4% to about 40% by weight based on the weight of the dry webs being bonded has been found desirable.

After the binder material has been applied to the fibrous web and set, either by regenerating, curing, heating, or drying, the bonded fibrous web in a relatively relaxed condition to permit shrinkage is passed over internally heated speed-controlled drying cans or through a heated oven maintained at a temperature sufficiently high to activate and shrink the heat-shrinkable fibers. Overfeeding may be resorted to in order to provide the desired slack for shrinking or to control the extent of the shrinking.

The exposure temperature on the drying cans or in the oven is determined by the nature of the heat-shrinkable fibers. Fabric temperatures as low as about 150° F. have been found satisfactory for some fibers, whereas as high as about 400° F. has been found desirable for other fibers. Temperature ranges of from about 240° F. to about 290° F. are preferred. Higher temperatures may be used where there is no damage to any of the fibers in the nonwoven fabric.

The time exposure is interdependent upon the temperature and a normal heating time of from about 15 seconds

up to about 5 minutes, and preferably from about 1 minute to about 2 minutes, is found satisfactory. Other things being equal, it has been found that the exposure time may be decreased by using a higher temperature, and that a lower temperature may be used in some cases to avoid fiber damage by using increased exposure periods. Subsequent to the development of the heat-shrinkable properties, the three-dimensional nonwoven fabric is forwarded for further processing as desired or required.

In FIG. 3 there is illustrated a nonwoven fabric **32'** after it has been treated by the apparatus and methods of the present invention. The nonwoven fabric **32'** comprises a lower layer **12'** of heat-shrunken fibers and an upper non-heat-shrunken layer **16'**, along with crests and troughs of waves or ripples which are created during the heat-shrinking process. In this way, surface interest is created, along with an enhanced three-dimensional effect.

In FIG. 4 there is illustrated apparatus and method suitable for carrying out the principles of the present inventive concept. The nonwoven fabric **32** is composed of a web **16** of non-heat-shrinkable fibers, which is positioned on a second web **12** of heat-shrinkable fibers. The webs **12** and **16** are passed between rotatable guide rolls **28**, **30**, over rotatable guide roll **34**, and are bonded together by being passed through the pressure nip of a backing roll **36** and an immersion roll **38** in a binder bath **40**. The impregnated nonwoven fabric is then passed over guide roll **42** and forwarded for further processing.

The binder is set by being regenerated, cured, heated or dried, as desired or required for the particular binder involved, in a setting unit **50**, and the bonded nonwoven fabric is then heat-treated in an oven **60** whereby the heat-shrinkability properties are activated to contract and increase the density of the heat-shrinkable layer and whereby the three-dimensional effect is developed. If desired, the heating oven may be replaced by a plurality of internally-heated, separately speed-controlled drums and the nonwoven fabric passed in direct contact therewith. The finished fabric may then be forwarded for product wind-up or other processing, as desired.

The invention will be further illustrated in greater detail by the following specific examples. It should be understood, however, that although these examples may describe in particular detail some of the more specific features of the invention, they are given primarily for purposes of illustration and the invention in its broader aspects is not to be construed as limited thereto.

Example I

A card web weighing 180 grains per square yard and comprising 50% by weight of 1½ denier, 2-inch staple length viscose rayon and 50% by weight of cotton is plied with a second card web weighing 180 grains per square yard and comprising 50% by weight of 1½ denier, 2-inch staple length viscose rayon and 50% by weight of 1.8 denier, 2-inch staple length "Rhovyl 55" fibers (heat-shrinkable polyvinyl chloride fibers made by Societe Rhovyl). The plied webs are bonded with an over-all binder by immersion in an impregnating bath. The binder used is a combination thermosetting-thermoplastic resin comprising melamine-formaldehyde and "Rhoplex B-15" (an ethyl acrylate resin binder made by Rohm & Haas). The percent binder add-on is about 25% by weight, based on the weight of the nonwoven fabric. The surface coverage is about 100%. The binder is dried at 200° F. The dried web is then heat shrunken by exposure to heat at 245° F. to yield a random rippled nonwoven fabric. The weight of the bonded nonwoven fabric prior to the heat treatment is about 430 grains per square yard. Subsequent to the heating, the fabric weighs about 670 grains per square yard. Such a fabric is suitable for use as a disposable face towel. It is soft, bulky and lofty and possesses increased absorbency due to the increased rippled surface area. It has an excellent appearance and an unusual rippled surface interest.

Example II

A three-layered fibrous structure is prepared as follows: the outer 2 layers each weigh 120 grains per square yard and comprise 100% by weight of 3 denier, 2-inch staple length viscose rayon, and the center layer weighs 120 grains per square yard and comprises 60% by weight of 3-denier, 2-inch staple length polypropylene fibers and 40% by weight of 3 denier, 2-inch staple length viscose rayon fibers. The three layers are over-all saturated with a combination binder comprising "Rhoplex B-15" (a soft acrylate resin consisting primarily of ethyl acrylate) plus a polyethylene dispersion. The percent binder add-on is about 20% by weight. The surface coverage is approximately 100%. The bonded nonwoven fabric is dried and calendered at a temperature of approximately 290° F. and is heat-shrunken by exposure in a relaxed condition to a temperature of approximately 350° F. for a period of 3 minutes. The center layer shrinks approximately 22% causing the two outer layers to buckle and to form a series of wavy ripples extending across the width of the fabric. The ripples are not regular but vary in length and width and do not extend exactly at an angle of 90° to the direction of predominant fiber orientation, but rather meander across the fabric somewhat generally at an angle of 90° to the predominant fiber orientation.

The resulting fabric is suitable for use as a dusting cloth. It is soft, bulky and lofty and possesses excellent absorbency and soil adherency due to the increased surface area created by the wavy ripples. Its appearance is excellent and its rippled surface interest is unusual.

Example III

A three-layered fibrous structure is prepared as follows: the outer two layers each weigh 120 grains per square yard and comprise 50% by weight of 3 denier, 2-inch staple length viscose rayon and 50% by weight of cotton and the center layer weighs 120 grains per square yard and comprises 50% 3 denier, 2-inch staple length viscose rayon and 50% by weight of "Dynel" acrylic fibers. The three layers are bonded in over-all fashion by immersion in an impregnating binder bath. The binder used is "HA-8" (an ethyl acrylate self-crosslinking resin binder made by Rohm & Haas). The percent binder add-on is about 20% by weight. The surface coverage is about 100%. The printed nonwoven fabric is dried at approximately 200° F. and is then heat shrunken at a temperature of about 250° F.

The center layer shrinks considerably causing the two outer layers to buckle and form a series of random wavy ripples extending generally across the width of the fabric. Such a material is suitable for use as a dusting cloth. It is soft, bulky and lofty and possesses excellent absorbency due to the increased surface area created by the wavy ripples. Its appearance is excellent and its rippled surface interest is unusual.

In some instances, it is desired that the rippled effect be accentuated and that the ripples themselves have some body or hand. This may be accomplished by positioning two fibrous webs of non-heat-shrinkable fibers on one side of a heat-shrinkable web and then exposing the same to fiber-shrinking temperatures. Each ripple or wave will have double thickness and provide a firmer body thereto. In any variation, a non-heat-shrinkable fibrous web and a layer of creped tissue are bonded to a heat-shrinkable web, with the layer of creped tissue next to the heat-shrinkable web. Subsequent exposure to heat-shrinking temperatures provides a double-thickness ripple with a creped tissue inside the rippled fibrous web to provide a crisp fullness thereto.

Although several specific examples of the inventive concept have been described, the same should not be construed as limited thereby nor to the specific substances or constructions mentioned therein but to include various other equivalent substances and constructions as set forth in the claims appended hereto. Weights, dimensions and other physical properties referred to herein refer to the fibrous webs or nonwoven fabrics, prior to the heat-shrinking process, unless specifically stated otherwise. It is understood that any suitable changes, modifications and variations may be made without departing from the spirit and scope of the invention.

What is claimed is:

1. A method of making a laminated, bonded, nonwoven fabric having good loft, a full-bodied hand, and three-dimensional surface interest which comprises: bonding together at least two layers of nonwoven fibrous materials, each of said layers being impregnated with a bonding agent which is applied to substantially 100% of their total surface area whereby the fibers of each individual layer are bonded together with said impregnating agent at their contacting areas to form a self-sustaining web, the fibers adjacent the coextensive surfaces of the respective webs being bonded with said impregnating agent at their contacting areas throughout the coextensive surfaces of the respective superimposed webs one of said layers comprising fibers having a greater propensity toward shrinkability than the fibers of another of said layers; and treating said bonded layers to cause said layer comprising the fibers having a greater propensity to shrinkability to shrink to haphazardly rupture some of the bonds uniting the two webs, whereby the layers separate from each other in undetermined portions thereof, said layers remaining bonded to each other only in an undetermined pattern of common binder areas, the portions of said layers which are not bonded together extending away from each other in rippled areas of high loft and full-bodied hand, thus providing three-dimensional surface interest.

2. A method of making a laminated, bonded, nonwoven fabric having good loft, a full-bodied hand, and three-dimensional surface interest which comprises: bonding together at least two layers of nonwoven fibrous materials, each of said layers being impregnated with a bonding agent which is applied to substantially 100% of their total surface area whereby the fibers of each individual layer are bonded together with said impregnating agent at their contacting areas to form a self-sustaining web, the fibers adjacent the coextensive surfaces of the respective webs being bonded with said impregnating agent at their contacting areas throughout the coextensive surfaces of the respective superimposed webs, one of said layers comprising fibers having a greater propensity toward heat shrinkability than the fibers of another of said layers; and heating said bonded layers to cause said layer comprising the fibers having a greater propensity to heat shrinkability to haphazardly rupture some of the bonds uniting the two webs, whereby the layers separate from each other in undetermined portions thereof, said layers remaining bonded to each other only in an undetermined pattern of common binder areas, the portions of said layers which are not bonded together extending away from each other in rippled areas of high loft and full-bodied hand, thus providing three-dimensional surface interest.

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