Nov. 7, 1950 H. A. SECRIST 2,528,793

COTTON FELT AND METHOD OF MAKING THE SAME

Filed Jan. 26, 1946 3 Sheets-Sheet 1

Fig. 1.

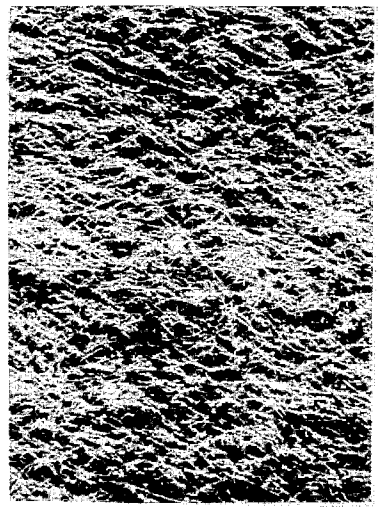
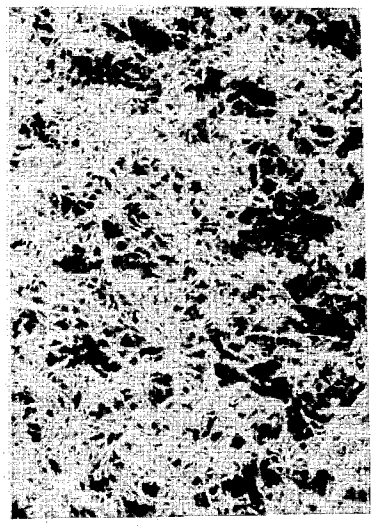


Fig. 2.



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COTTON FELT AND METHOD OF MAKING THE SAME

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Fig. 3.

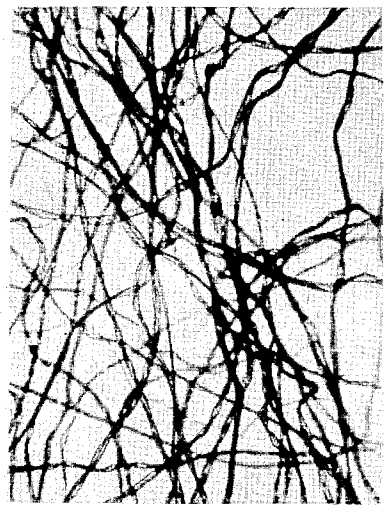
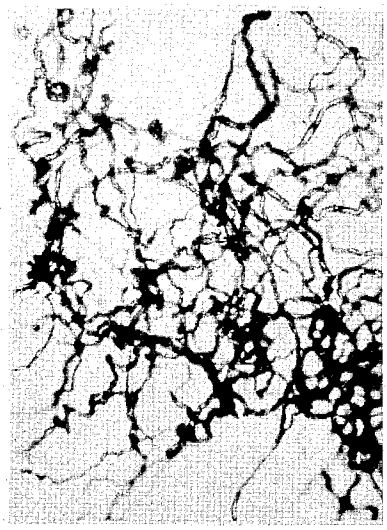


Fig. 4.



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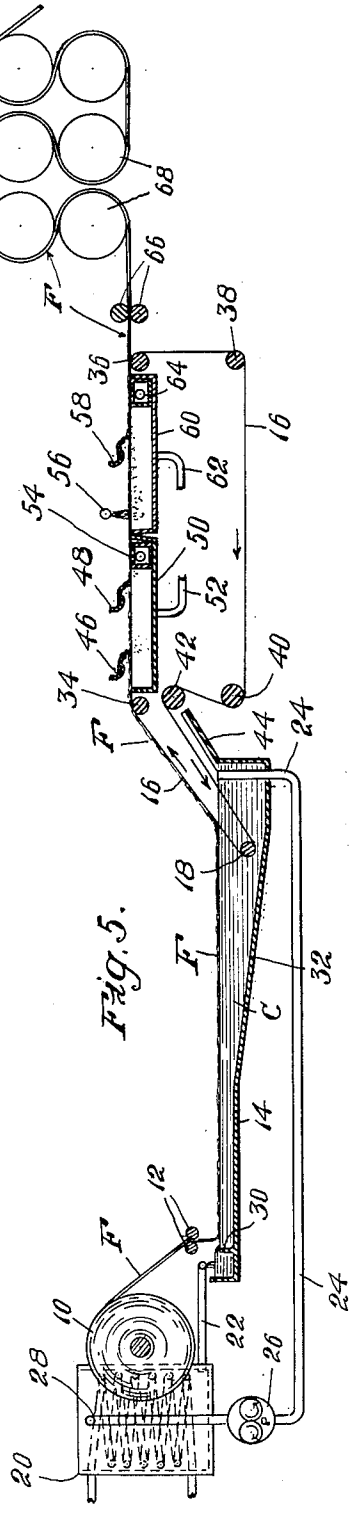


Fig. 5.

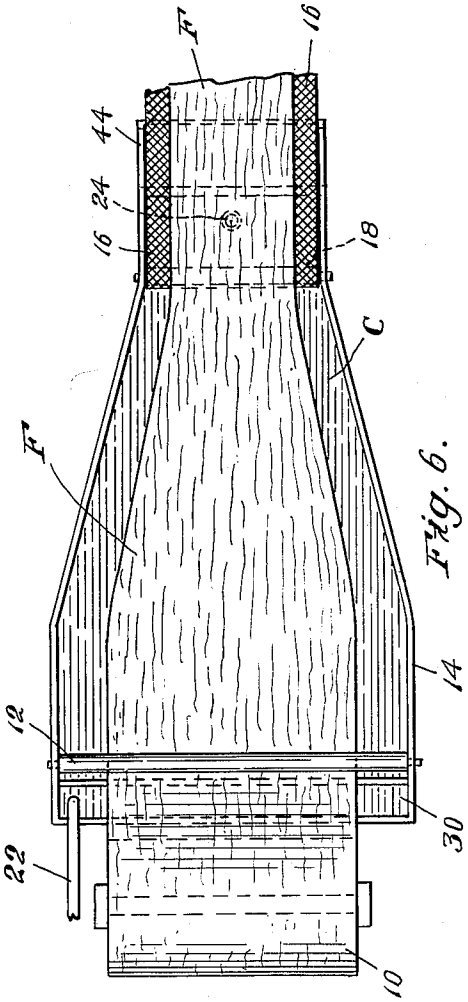


Fig. 6.

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2,528,793

COTTON FELT AND METHOD OF MAKING THE SAME

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Application January 26, 1946, Serial No. 643,799

14 Claims. (Cl. 8—117)

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This invention concerns felted cotton fiber textile materials, and apparatus and methods of making the same. More particularly, the invention provides for the first time in the art a true felt which may be composed wholly of cotton textile fibers, and a process for producing such a felt. This felt is soft, porous, highly conformable, flexible and extensible; has adequate strength for many textile uses; and may be employed for many of the purposes for which wool felts are used. It comprises inter-curled and entangled cotton textile-length fibers having artificially-induced kinks, twists and bends.

It has long been known that cotton fibers lack the natural felting properties of wool and similar fibers. Cotton fibers do not respond to the wool felting process, that is, to mechanical manipulation in the presence of moisture and heat. Under such conditions they do not condense, tangle and interlock and do not produce a felt or a material of adequate tensile strength for textile usages.

To obtain such strength in an unwoven textile material of cotton fibers, it has heretofore been necessary to employ fiber-to-fiber bonds to lock the fibers together into a coherent body by the addition to the fiber mass of a binding agent, or, by including special binder fibers. These bonded fiber products, which are dependent upon a binding medium (mass or fiber) and adhesive bonds for structural integrity, do not possess felt-like pliability and extensibility, but have low yieldability and tend to have the bonds ruptured when bent at small radius.

I have discovered that I can so handle a mass or body of intermingled cotton fibers of textile-length in the presence of chemicals having a substantial swelling action on cellulose, preferably aqueous caustic alkali solution, as to produce a writhing, curling, kinking, looping, and twisting in all directions with resultant contracting, and decreasing the span, of individual fibers which cause them to entangle, entwist and felt, drawing bodily together with resultant extensive shrinking (i. e., longitudinal and lateral contraction—area condensation) of the mass of fibers, but without significant loss of fiber weight or destruction of fiber form. The fiber mass so treated and shrunk, while wet with the treating chemical, is extremely limp and weak, due apparently to a softening of the individual fibers. By this process, however, I am able, upon removal of the treating chemical, to produce my novel product—a strong, extensible, conformable felt consisting of fibers having substantially their natural strength but arranged in a new artificially-induced curled, kinked, twisted, entangled, and interlooped condition. Moreover, the removal of the treating agent is accomplished without reducing, in fact while often increasing, the resultant contracted condition of the frictionally interlocked fiber mass, produced by the chemical action.

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As the characteristic high flexibility, extensibility, and compressibility of the felt indicate, the process produces little or no loss of individual fiber identity, that is, no material fusing together of fibers. The strength of the product, as in a wool felt, derives from the fact that the fibers have curled and kinked about each other, producing a new and extensive fiber entanglement and interlocking which greatly increase the mutual frictional engagement of the fibers and hence the tensile strength of the material. The same factors, coupled with substantially complete fiber identity and freedom, though with an overall-shortening of length due to kinking, twisting and bending, serve to explain the high extensibility and flexibility of the material. The end product is soft because the fibers are not matted down nor interfused and have a loft such as that of most wool felts.

The physical properties and structural characteristics of the cotton felts are believed to be the result of the interaction of two factors: One, the original arrangement of the fibers of the untreated cotton brought about by such mechanical processes as carding or other means of original dry-assembly; and, two, the subsequent profound modification of the original fiber configuration and course of the fibers by chemical treatment. It is thought that basically the ability to produce these changes is determined by the structure of the cotton fiber itself which has as a natural pattern a helical arrangement of its ultra-structural units which are reversed in direction at regular intervals. Thus when the fiber is treated it swells, accompanied by a release of the natural set of the fiber and a release of the energy forces of the fiber. This en-

ergy release is associated with a helical twisting, and/or untwisting, of the fiber on its long axis and a three dimensional writhing which results in the appearance of major and minor kinks, regional and localized coiling, and sharp twisting and even reversal of its course. As the fibers are in intimate relation to one another, such writhing and movement of the fibers causes them to become entangled with one another. Furthermore, all such changes contribute directly to the conversion of the fibers into forms which enable them to interlock readily with one another to produce the physical pattern described above. The reaction of the fibers in intertwining and interlocking is so pronounced that when superposed layers of fibers are treated and the process is carried sufficiently far, the constituent layers are intimately locked together to produce a continuous system.

During the treatment, the fibers assume a new and greatly entangled and interlocked relation with one another. Removal of the treating solution after the fibers have assumed their newly entangled, kinked and twisted condition, as I have discovered, causes the fibers to become set in a new conformation and configuration, and, thereafter, the dried fibers are reluctant to assume any other configuration, and resist any forces exerted upon them tending to change their configuration. As the felted product is essentially an entangled, interlooped and frictionally interlocked mass of the individual set fibers, and as such elemental fibers resist changes in configuration, the felt itself attains thereby a high degree of resistance to forces tending to interrupt its continuity of structural coherence or to deform it from its contracted condition.

The extent of fiber curling, kinking and entanglement produced, upon which the strength, extensibility and other unique qualities of the product are dependent, corresponds closely to the extent to which the dry-assembled fiber aggregate undergoes a permanent lengthwise and widthwise contraction in the process. The amount of such contraction that can be obtained is a controllable variable from as high as 95% area-contraction down to as little as 40%, with a corresponding range of products differing in the extent to which the new felt-like properties are realized.

The variable conditions or factors of the process, by which are determined and controlled the extent to which the desired new characteristics are imparted to the fiber aggregate, are numerous and concern not only the chemical treatment itself but also the manner in which the fiber mass is prepared for the chemical treatment and is processed following the chemical treatment.

It is preferred that the fibers be first cleaned, for example by boiling and bleaching. The initial closeness of association of the fibers has some effect on the extent of the felting action obtained. Superimposed, unpressed films of dry-assembled fibers, preferably carded or garnetted cotton fiber webs, are suitable for treatment in the process and thereby acquire the new felt-like properties to a useful extent. I have found, however, that by increasing the density of such a carded or garnetted fiber layer, by a prepressing operation, the properties of the resulting felt may be substantially altered. For example, felts made from unpressed webs are usually soft and thick and are characterized by high extensibility and permeability, while those made from heavily hot-calendered webs, under conditions of say 350° F. and 1800 pounds per inch of width, are stronger, more dense, thinner, and less extensible. It has been found, however, that the most useful commercial felts are made from lightly cold-pressed webs, for example under pressure of 10 pounds to 20 pounds per inch width. In the ensuing chemical treatment the pressed webs fluff and full as they contract, tending to increase in thickness.

The arrangement of the fibers in the body or mass thereof to be treated also has an effect on the results realized. They should be thoroughly intermingled and more or less randomly intermixed, with a fairly even distribution between fibers arranged longitudinally and those arranged transversely of the layer for more nearly balanced longitudinal and lateral strength in the product. Furthermore, since the process depends upon writhing, kinking and looping of individual fibers thus to become mutually entangled, it is important that the fibers have some degree of freedom of motion during the treatment and that the association of the fibers be such as to permit such motion.

Any suitable means may be employed for initially assembling the fibers but a satisfactory arrangement of fibers is obtained in carding, garnetting or the like. I prefer, however, initially to form a body of several parallel superimposed sheets of the fibers which have been carded or otherwise assembled. It is a characteristic of my product, when made from multiple parallel superposed sheets, that the writhing of the fibers during treatment effects a fiber entanglement and interlocking between fibers of adjacent carded sheets so as to form a homogeneous product which has substantial resistance to delamination. Thus when carded sheets are superposed in parallel relation the resultant body is usually stronger longitudinally than laterally, apparently because the carding produces a somewhat greater distribution of fibers arranged longitudinally than of those arranged laterally of the sheet. On the other hand, the product obtained by cross-laying alternate carded sheets in forming the body is of more evenly balanced strength longitudinally and laterally, but this product has a greater tendency to delaminate under stress. For uniformity of the final product, the fiber distribution should be fairly even throughout the body, as it is in a carded fiber sheet.

As previously stated, the preferred treating chemical of the process is an aqueous solution of caustic alkali such as sodium, potassium, or lithium hydroxide. Other basic cellulose swelling agents may be employed, such as solutions of sodium zincate, quaternary ammonium bases such as benzyl trimethyl ammonium hydroxide, and the like. Aqueous sodium hydroxide solution is usually employed because it is easier to work with and control, comparatively inexpensive, and produces entirely satisfactory results. For convenience, all of said materials are herein termed "causticizing agents."

Using aqueous sodium hydroxide solutions, satisfactory results have been obtained with solution concentrations of at least 8% and less than 30% NaOH at temperatures from just above the freezing point of the solutions to +25° C. Preferably, and for best results, such solutions are used in concentrations of at least 10% and less than 18% NaOH at temperatures from −10° C. to +15° C. Other reagents may be employed at corresponding effective strengths and temperatures.

The manner in which the fiber body is sub-

jected to the chemical treatment has a controlling effect upon the results produced. Since the felting action of the chemical on the fibers is necessarily accompanied by shrinkage of the fiber body, during the chemical treatment the body must be freed of restraints which would prevent shrinkage, such as tension and substantial surface friction. I have found that maximum effects are obtained by floating the fiber body without restraint, either longitudinal or transverse, in a bath of the treating solution. If, instead, the fiber is restrained, to any material extent, from freely contracting during the chemical treatment, felting action and shrinkage are seriously inhibited. Thus, if instead of floating freely, the sheet is held under longitudinal tension or drag, felting action and shrinkage are seriously impaired. I may, for example, provide the requisite freedom from tension of the fiber sheet while floating in the bath by overfeeding the dry-assembled sheet onto the surface of the liquid, that is, feeding the fiber sheet to the bath faster than it is withdrawn therefrom, the extent of this overfeed being at least equal to the extent of the desired longitudinal shrinkage of the sheet. Alternatively, the requisite freedom may be provided and tensile strain on the material avoided by overfeeding the sheet down an inclined trough while supporting it through the medium of underlying causticizing liquid and subjecting it to the action thereof, the weight of the liquid and of the material aiding longitudinal condensation of the moving sheet. If the trough be formed, as is preferable, with a transversely curved cross-section, the transverse contraction may also be augmented by gravity, i. e., the weight of the sheet and causticizing material.

The maximum felting, contractive effects of the chemical are realized in a short time, normally in one-half to three minutes, and the fiber sheet is then removed from the bath and treated to remove the chemical, preferably promptly because over long exposure to the chemical may produce undesirable gelatinization of the fibers. The fiber sheet at this stage is extremely limp and weak, and must be treated with great care, as even the slightest tension or pull is likely to cause disintegration or at least undesirable stretching of the sheet. To avoid such tension, the sheet is positively supported throughout its area after its causticizing treatment and during its subsequent treatment for removal of the chemical, by carrying it on a moving screen, belt, or other suitable supporting means.

The chemical solution is washed from the shrunken fiber sheet, preferably by flowing a large quantity of water on the fiber while it is carried on a moving screen or like foraminous structure through which the liquid drains. Preferably, although not necessarily, the fiber is then neutralized with acid or other suitable agent, such as acetic acid or sodium bicarbonate, and again washed. The fibrous material, washed free of treating chemicals, is finally dried to complete the processing. After washing, the fiber sheet has attained sufficient strength to permit normal handling during the drying operation.

If desired, certain improvements in mechanical properties may be obtained by a wet-stretching operation. Breaking strength and modulus of elasticity may be increased by controlled stretching after the treating solution has been substantially removed. If the treated felt has a greater orientation of fiber in one direction than another, as evidenced by the greater strength or greater modulus of elasticity in that direction, the sheet may be made more nearly isotropic by controlled stretching in the weaker direction.

The novel felts and the preferred method and apparatus for their manufacture will be further described with reference to the appended drawings, wherein:

Fig. 1 is a photomicrograph (20x) showing a plan view of a typical carded mass of cotton fibers prepared for felting by causticizing according to the invention;

Fig. 2 is a photomicrograph (20x) showing a plan view of a felt produced by causticizing, washing and drying according to the invention a carded mass of cotton fibers as illustrated in Fig. 1, the layer having sustained an area shrinkage of approximately 80% in the felting;

Fig. 3 is a photomicrograph (80x) showing a plan view of individual cotton fibers teased from the carded mass shown in Fig. 1;

Fig. 4 is a photomicrograph (80x) showing a plan view of individual cotton fibers teased from the felt shown in Fig. 2;

Fig. 5 is a diagrammatic side elevation view of a preferred apparatus of the invention for performing the causticizing, washing and drying steps of the process as a continuous operation; and

Fig. 6 is a plan view of a portion of the apparatus shown in Fig. 5.

Referring to Figs. 1 to 4 of the drawings, the cotton fibers of the web prepared for felting (Figs. 1 and 3), in this instance by carding, have their usual physical structure which is essentially that of a straight, flattened tube twisted helically along its axis, as clearly appears in Fig. 3. These fibers are associated together by the carding operation into a more or less random criss-cross network in which their natural form is retained and the fiber direction is mainly parallel to the surfaces of the web. Because of their straightness and smoothness, the fibers do not tangle with one another but are loosely meshed with low mutual frictional engagement which permits them to be readily dissociated and imparts but very small tensile strength to the web.

In the felted product (Figs. 2 and 4) the fibers have undergone profound changes both in their physical form and in their structural interrelationship. As clearly appears in Fig. 4, the fibers have lost their usual straightness and smoothness and are now curled, twisted and distorted into highly irregular configurations. They are generally characterized by the presence of numerous irregularly spaced major and minor kinks, crooks and bends. In some cases the fibers show regional coiling or tortuous, corkscrew-like bends and twists. They may even twist completely backward in their course. They have the appearance of being gnarled and even knotted. In cross-section the fibers are cylindrical rather than flat.

These changes in the structure, shape, configuration and the shortened span of the individual fibers, together with the much closer association of the fibers by virtue of the contraction in the aggregate, produce a thorough entanglement of the fibers which curl and twist about one another at their points of mutual contact (Figs. 2 and 4). The felted fiber mass has a frosty or woolly appearance (Fig. 2), the course of individual fibers is no longer readily apparent, the directional lay of the fibers in the carded web (Fig. 1) and their arrangement parallel to

the surfaces of the web, is substantially modified. As appears in Fig. 2, there is a tendency for the fibers to group about centers of high fiber concentration and mutual contact, forming a sponge-like network of fiber clots interspersed with small voids.

Felts which have been less highly shrunken than the product shown in Figs. 2 and 4 exhibit like changes in physical structure and interrelation of the fibers but to a somewhat lesser extent. In general, these changes are readily observable under moderate magnification.

Referring now to Figs. 5 and 6 of the accompanying drawings, which illustrate preferred apparatus and method for performing the chemical treatment and subsequent steps of the process as a continuous operation; 10 designates a roll, for example, of cotton fiber sheet F prepared for the causticizing treatment, preferably by superimposing carded webs of boiled and bleached cotton fiber as previously described. The sheet F is unwound from the roll 10 by being drawn between suitably driven feed rolls 12 which feed the sheet onto the surface of a bath of the treating chemical or caustic C maintained in a tank or trough 14.

The sheet F floats in the caustic toward the opposite end of the tank, shrinking substantially both longitudinally and laterally as it proceeds. Near the far end of the tank the shrunken sheet moves over and is advanced by the underlying forwardly moving surface of a conveyor screen 16 which passes about a roller 18 located in the liquid in the tank and is carried thereby at a gradual incline from the tank. The feed rolls 12 are driven by suitable driving connections (not shown) to over-feed the sheet onto the bath, that is, to feed the sheet to the bath at a rate faster than the shrunken sheet is carried therefrom by the conveyor screen 16.

The refrigerated caustic solution is continuously supplied at a controlled rate to the tank 14 from a refrigerated container 20 by a feed pipe 22 at the fiber-feed end of the tank and continuously flows from the tank by means of an outlet pipe 24 at the opposite end of the tank leading to a pump 26 which returns the caustic to container 20 through pipe 28.

Thus there is provided a continuous controlled rate of flow of the caustic in the tank from the feed end toward the outlet end, which flow or current carries the freely floating fiber sheet toward the conveyor 16. The caustic is discharged by feed pipe 22 into a weir 30 at the feed end of the tank and flows over the lower front wall of the weir in a stream of uniform depth extending the full width of the tank. The outlet into pipe 24 is located at the front end of tank 14, beyond the roller 18 and the portion of screen 16 passing thereover so that the flow of caustic is through the screen, positively depositing the fiber sheet thereon.

The bottom of tank 14 slopes downwardly at 32 from a point a short distance forwardly of the point of feed of the sheet onto the caustic to a point near the front end of the tank. Also, as shown in Fig. 6, the walls of the tank converge inwardly from a point near the point of feed to adjacent the forward end of the tank. The increase in depth of the bath produced by the downwardly sloping bottom portion 32 of the tank more than offsets the loss in width due to the converging walls of the tank, with the result that the rate of flow of the caustic in the tank toward the outlet decreases as it passes over the inclined bottom portion 32.

The rate of rotation of the feed rolls 12 is carefully correlated to the speed of the withdrawal screen 16 to provide the overfeeding previously mentioned. For maximum effectiveness of the chemical treatment, the controlled rate of feed of these rolls should be approximately according to the formula

$$R = W \times \frac{100}{100 - P}$$

where R is the rate of feed and W the rate of withdrawal in units of length of the fiber sheet per unit of time, and P is the maximum percent of the longitudinal shrinkage which the chemical is capable of producing in the fiber sheet floated therein without restraint. The value for P can be readily determined by floating a test length of the fiber sheet in the chemical and comparing its shrunken length to original length when the shrinking action of the chemical is complete or has been completed to the extent desired. The varied rate of flow and length of the chemical bath from the feed rolls 12 to the conveyor 16 should be such as to provide sufficient time for completion of the shrinking or felting effect which is usually of the order of one-half to three minutes.

The rate of feed of the caustic to the tank and the rate of its withdrawal are adjusted so that the initial flow of the caustic in the shallow feed end of the tank approximates in speed the rate of feed of the fiber sheet into the tank, whereas the rate of flow in the deeper front end of the tank where the caustic passes through the screen is considerably slower, approximating the rate of withdrawal of the fiber sheet from the caustic by the screen. The point where the tank begins to deepen is approximately the point where the sheet is first thoroughly wet out by the caustic and the shrinking action commences. Thus, as the fiber sheet shrinks, the rate at which it is advanced by the flow of caustic diminishes from approximately the rate of feed of the sheet into the caustic to approximately the lesser rate of withdrawal of the shrunken sheet from the caustic. This decelerated flow of the caustic greatly facilitates longitudinal shrinkage of the fiber sheet, since the frictional resistance of the liquid to the longitudinal shrinking forces generated in the sheet by the kinking and curling action of the caustic on the individual fibers is thereby reduced or even completely eliminated.

Likewise, the transverse narrowing of the tank toward its forward end produces some lateral component of flow of caustic in the bath which tends to facilitate the transverse shrinkage of the sheet.

The screen conveyor 16 passes from the roller 18, where it receives and carries the wet, causticized and contracted fiber sheet along the upwardly inclined path to a roller 34, thence horizontally to a roller 36, thence downwardly and back under rollers 38 and 40 and over roller 42 to roller 18. A trough 44 slants forwardly and upwardly from the front end of the tank under the conveyor screen to catch caustic draining from the sheet as it passes upward to the roller 34, and returns the caustic to tank 14.

The screen, in passing from roller 34 to roller 36, carries the sheet first under two successive weir troughs 46, 48 which gently flood wash water over the surface of the sheet. This wash water drains through the sheet and conveyor

screen washing out the bulk of the caustic, and is collected in a trough **50** immediately below the screen, from which trough a drain pipe **52** may lead to a caustic recovery or concentrating apparatus (not shown). A suction box **54** at the front end of trough **50** applies suction to the sheet through the screen to complete the removal of wash waters.

After leaving the suction box **54**, the sheet is carried beneath a spray head **56** which applies a light spray of neutralizing liquid such as dilute acetic acid solution to the sheet, and then under a weir trough **58** which floods water on the sheet to wash out the neutralizing acid. A trough **60** collects the acid and wash water draining from the sheet through the screen, from which trough a drain pipe **62** may lead to an acid recovery system (not shown), or to waste. A suction box **64** is provided at the front end of trough **60** to complete the removal of wash water and acid.

As it emerges from the caustic bath the fiber sheet is extremely limp and weak, so that the mere back drag of its own weight, if it were attempted to lift or pull it from the bath, would either cause it to disintegrate or to stretch so extensively that the useful felting effects of the caustic treatment would be substantially reduced or even completely lost. By positively supporting and lifting the sheet out of the caustic in the manner herein illustrated, the full effects of the caustic treatment are preserved. Preferably, as shown, the wash water is flooded gently, that is, with low impact force, onto the sheet, since the impact of a heavy spray might be sufficient to break up the sleazy fiber mass.

However, upon completion of the washing and neutralizing steps, the fiber sheet has, due to removal of the caustic, become essentially set in its changed, felted condition and has gained substantially its full final wet strength. It may, therefore, be handled with less support and care in further treatment without danger of material permanent stretching and loss of felting effect.

From the last suction box **64**, the sheet, in the arrangement of apparatus shown, passes off the conveyor between squeeze rolls **66** to drying apparatus which, as shown, comprises a series of heated rotary cans or drying drums **68** of conventional form. Other methods of drying may be employed, for example, by festooning the sheet in a heated chamber, or by passing between banks of infra-red lamps. Upon leaving the drying cans **68**, that is, after the drying has been completed, the sheet is in its final felted form.

To illustrate further a suitable practice of the process and production of the felt products of the invention, the following example is given:

The webs of cotton fibers, mainly from ½ inch to 1 inch long, from six cards, were superposed in parallel, forming a single sheet which was passed through cold rollers under a pressure of about 10 pounds per inch width of the rollers. This lightly pressed sheet weighed 41.0 grams per square yard and was 0.117 inch thick measured under a load of one gram per square inch. The density of this carded fiber sheet was about 1.0 pound per cubic foot.

The lightly pressed sheet was floated on a 14% solution of sodium hydroxide at a temperature of −5° C. After the material had attained maximum shrink, the sheet was removed from the solution by means of a moving screen, rinsed with water, acidified with acetic acid, again washed with water, and dried.

The finished material sustained an area contraction of 80%, had a density of 6.0 pounds per cubic foot and a thickness of 0.121 inch under a load of 25 grams per square inch. The extension at break in the lengthwise direction was 107% and in the widthwise direction 131% under loads of 5.6 pounds and 1.2 pounds respectively per inch of width. Its permeability was 88 cubic feet of air per minute per square foot measured in a standard permeability testing apparatus (made in accordance with the Schiefer-Boyland design described in the Bureau of Standards Report, R. P. 1471) at standard temperature and humidity.

In making strength comparisons between felts of different thicknesses and densities I make use of what I term "corrected load," which is the actual load at break (in pounds per inch of width of the sample tested) divided by the weight in pounds of one square yard of the felt. This corrected load takes into account differences in weight of the compared felts, in effect, giving the strength of a unit quantity or weight of cotton fiber in different felts.

In the foregoing example, the felt produced had a corrected load of 10.4 lbs. in the lengthwise direction and 2.3 lbs. in the widthwise direction.

Within limits, the process is subject to considerable variation to produce different degrees of felting action and products which differ somewhat in the extent to which they possess the characteristic properties of the felts of the invention. For example, as a general rule, other conditions being equal, increasing the temperature of the caustic tends to diminish the degree of felting as measured by area shrinkage.

A denser felt having less extensibility and porosity but greater strength can be produced by compressing the laminated card webs, prior to causticizing, under heavy pressure of the order of 1500–1800 pounds per inch of width of pressure rollers. By cross-laying the successive card webs so that their long axes are at approximately 90° angles to each other, a felt of more evenly balanced strength lengthwise and widthwise may be obtained.

In general, the felts of this invention which, as previously stated, will have sustained an area shrinkage of at least 40% in causticizing, have an extensibility of at least 30% in either dimension, and preferably at least 75% in one dimension. Their dry strength corresponds to a corrected load at break, computed as previously explained, of at least about 5.0 pounds in the lengthwise direction and at least 1.3 pounds in the widthwise direction, and their wet strength is approximately one-half their dry strength. They have a permeability of at least 15 and generally less than 200 cubic feet of air per minute per square foot per 0.1 inch of thickness as measured by the standard apparatus above referred to, and a density of at least 3.0 pounds per cubic foot.

While the products of this invention are prepared by chemically treating cotton fibers, and the novel characteristics of such products are mainly dependent for their structural integrity on the presence of such fibers, it is possible to prepare many useful articles in which the felted cotton fibers serve as the main structure in which other fibers, for example, cellulosic or non-cellulosic, thermoplastic, natural or synthetic fibers, such as kapok, wool, silk, vinyon, nylon, and regenerated cellulose may be dispersed. For

convenience, all the products of this invention even though they contain other fibers with the cotton fibers are referred to herein as cotton products or cotton felts.

The felts of this invention have many advantageous uses. Because of the high extensibility, flexibility, and conformability of the felts, they are more readily moldable than woven fabrics and may be molded by pressure, suction, etc. to shapes of such great irregularity as to break an equal thickness of laminated woven fabrics attempted to be shaped to a similar extent. Their high absorbency and porosity make them well suited as a base for impregnation with resins and other binders as, for example, to form artificial leather, and they are superior to materials previously used for such purpose in that, due to their great extensibility and contractability, they do not break when bent at small radii and thus cause cracking and weakening of the composite material, which has been a serious difficulty with prior base materials, such as the conventional paper or cotton wadding. Their high extensibility makes them especially suited for impregnation with binders such as the elastomeric resins, since they will stretch and return freely with the elastic binder without rupturing, forming a highly elastic material. They are also readily moldable to irregular shapes when impregnated with a moldable plastic binder.

The felts of the invention, although having many valuable properties similar to those of wool felts, have important advantages over wool felts. For example, unlike wool felts, these felts can be wetted without risk of causing further appreciable shrinkage and have pronounced resistance to alkalies and to high temperatures. They are more readily susceptible to dyeing. Furthermore, they do not contain proteins as do wool felts and, therefore, unlike the latter, are not attacked by moths and do not arouse allergic reactions. They are, therefore, particularly useful in clothing, for example, in shoulder pads, and in surgical dressings.

The extensibility of the felt may, if desired, be reduced by laminating it with fabric or yarn, for example, by laminating an 18 x 14 or 20 x 12 gauze between two pieces of the felt with a binder, such as latex. Such a laminated product has its extensibility restricted essentially to that of the gauze or other reinforcing material, but it retains substantially the extreme pliability and other properties of the felt alone. Also, if desired, the strength of the felt may be increased, although generally with reduced extensibility, softness and pliability, by added bonding agents which positively bond the fibers together. In such case, however, it is preferable to add or activate the binding agent after completion of the felting treatment, as, even if the binding agent be of such a character that it is not adversely affected by the chemical treatment, its fiber bonding action reduces the felting effect of the chemical treatment, and, indeed, if substantial quantities of activated binder are present, it prevents any appreciable felting action of the chemical. Furthermore, the presence of even a small amount of added binding material causes the product to have an uneven, rough, crinkled surface, and interferes with the permeability to fluids (liquid or gaseous), as well as other desirable physical characteristics of the finished product.

While the process has been described and illustrated as applied to the production of a continuous felt strip, it is not limited thereto. Thus, the process may be applied in similar manner to the production of pieces of felt of any desired size and shape. The pieces may be solid or they may be tubular, or, for example, conical shaped hat bodies. Where tubular bodies are felted in a collapsed state, a piece of light, non-reactive material may be placed in the interior of the tube to prevent felting together of the opposite collapsed walls of the tube during causticizing, the non-reactive material offering no substantial resistance to the shrinkage of the tube while yet serving as a barrier between its walls. The fibrous material treated may be in the form of rope or roving of tangled fibers, formed, for example, by rolling of a carded web.

Individual pieces or bodies of the fiber may, for example, be felted by the use of apparatus such as illustrated herein by dropping the pieces in succession into a caustic bath, floating the pieces in the bath while they shrink and simultaneously carrying them along the tank by a current of caustic which deposits them on an upwardly inclined conveyor screen, whereby they are carried out of the caustic and on which they are washed and acidified in like manner to the continuous strip.

In the practice of the invention, the cotton fibers employed are of textile length, that is, one-half inch staple or more, and generally from ¾ to 1½ inch staple. I have found that the presence of such fibers at least in major proportion is essential to the manufacture of strong felts, in that shorter fibers do not develop sufficiently the felting effects that are realized with the textile length fibers.

I claim:

1. The method of felting cotton fibers of textile length to form a coherent unwoven textile material which comprises subjecting a body comprising said fibers intermingled in dry-assembled sheet form to the action of a liquid causticizing agent for cellulose at low temperature while supporting said body by means of said liquid agent substantially without tensional stress and surface frictional restraint, thereby causing said fibers to intercurl, kink, and contract said body in area, and removing said causticizing agent from the fibers without substantially stretching said body, thereby fixing the fibers thereof in said intercurled and kinked condition and said body in area-contracted condition.

2. The method of felting cotton fibers of textile length to form a coherent unwoven textile material which comprises subjecting a body comprising said fibers intermingled in dry-assembled sheet form to the action of an aqueous NaOH solution of 8%–30% concentration and at a temperature between its freezing point and 25° C. while supporting said body by means of said solution substantially without tensional stress and surface frictional restraint, thereby causing said fibers to intercurl, kink, and contract said body in area, and removing the NaOH from the fibers without substantially stretching said body, thereby fixing the fibers thereof in said intercurled and kinked condition and said body in area-contracted condition.

3. The method of felting cotton fibers of textile length to form a coherent unwoven textile material which comprises continuously feeding and subjecting a sheeted body comprising said fibers intermingled in dry-assembled strip form to a liquid causticizing agent for cellulose at low temperature while continuously advancing said strip and said liquid agent substantially without ten-

sional stress and surface frictional restraint, thereby causing said fibers to intercurl, kink, and contract said body in area, and thereafter continuously moving said body at a lesser linear rate than said feeding and removing said causticizing agent from the fibers without substantially stretching said body, thereby fixing the fibers thereof in said intercurled and kinked condition and said body in area-contracted condition.

4. The method of felting cotton fibers of textile length to form a coherent unwoven textile material which comprises continuously feeding and subjecting a sheeted body comprising said fibers intermingled in dry-assembled strip form to a liquid causticizing agent for cellulose at low temperature while supporting said body substantially without tensional stress and surface frictional restraint in a forwardly moving stream of said liquid agent, thereby causing said fibers to intercurl, kink, and contract said body in area, separating the body from said stream at a lesser linear rate than said feeding and removing said causticizing agent from the fibers without substantially stretching said body, thereby fixing the fibers thereof in said intercurled and kinked condition and said body in area-contracted condition.

5. The method of felting cotton fibers of textile length to form a coherent unwoven textile material which comprises continuously feeding and subjecting a sheeted body comprising said fibers intermingled in dry-assembled strip form to a liquid causticizing agent for cellulose at low temperature while supporting said body substantially without tensional stress and surface frictional restraint in a forwardly moving but decelerating stream of said liquid agent, thereby causing said fibers to intercurl, kink, and contract said body in area, separating the body from said stream at a lesser linear rate than said feeding and removing said causticizing agent from the fibers without substantially stretching said body, thereby fixing the fibers thereof in said intercurled and kinked condition and said body in area-contracted condition.

6. As an article of manufacture, an unwoven fabric of intermingled unspun fibers comprising essentially, and primarily dependent for its integrity upon, frictionally interlocked cotton fibers of textile length, said cotton fibers being characterized by artificially-induced irregular kinks, twists, bends and curls, whereby the fibers are held together to form a conformable extensible coherent cotton felt, said felt having an extension of at least thirty per cent in at least one dimension.

7. As an article of manufacture, an unwoven fabric of intermingled unspun fibers comprising essentially, and primarily dependent for its integrity upon, frictionally interlocked cotton fibers of textile length, said cotton fibers being of shortened span and characterized by artificially-induced irregular kinks, twists, bends and curls, whereby the fibers are held together to form a conformable extensible coherent cotton felt, said irregular kinks, twists, bends and curls reducing the collective span of fibers by at least 40% and said felt having an extension of at least 30% in at least one dimension

8. As an article of manufacture, an unwoven fabric of intermingled unspun fibers comprising essentially, and primarily dependent for its integrity upon, frictionally interlocked cotton fibers of textile length, said cotton fibers being characterized by artificially-induced irregular kinks, twists, bends and curls, whereby the fibers are held together to form a conformable extensible coherent cotton felt, said felt having an extension of at least 30% in at least one dimension, and having a longitudinal corrected strength of at least 5 pounds.

9. As an article of manufacture, an unwoven fabric of intermingled unspun fibers comprising essentially, and primarily dependent for its integrity upon, frictionally interlocked cotton fibers of textile length, said cotton fibers being characterized by artificially-induced irregular kinks, twists, bends and curls, whereby the fibers are held together to form a conformable extensible coherent cotton felt, said felt having an extension of at least 30% in at least one dimension and having a wet strength of approximately one-half of its dry strength.

10. As an article of manufacture, an unwoven fabric of intermingled unspun fibers comprising essentially, and primarily dependent for its integrity upon, frictionally interlocked cotton fibers of textile length, said cotton fibers being characterized by artificially-induced irregular kinks, twists, bends and curls, whereby the fibers are held together to form a conformable extensible coherent cotton felt, said felt having an extension of at least 30% in at least one dimension and having other fibers dispersed therein.

11. The method of felting cotton fibers of textile length after boiling and bleaching to form a coherent unwoven textile material which comprises subjecting a body comprising said fibers intermingled in dry-assembled sheet form to the action of a liquid causticizing agent for cellulose at low temperature while supporting said body by means of said liquid agent substantially without tensional stress and surface frictional restraint, thereby causing said fibers to intercurl, kink, and contract said body in area, and removing said causticizing agent from the fibers without substantially stretching said body, thereby fixing the fibers thereof in said intercurled and kinked condition and said body in area-contracted condition.

12. As an article of manufacture, an unwoven fabric of intermingled unspun fibers comprising essentially, and primarily dependent for its integrity upon, frictionally interlocked boiled and bleached cotton fibers of textile length, said cotton fibers being characterized by artificially-induced irregular kinks, twists, bends and curls, whereby the fibers are held together to form a conformable extensible coherent cotton felt, said felt having an extension of at least thirty percent in at least one dimension.

13. The method of felting cotton fibers of textile length after cleaning to form a coherent unwoven textile material which comprises subjecting a body comprising said fibers intermingled in dry-assembled sheet form to the action of a liquid causticizing agent for cellulose at low temperature while supporting said body by means of said liquid agent substantially without tensional stress and surface frictional restraint, thereby causing said fibers to intercurl, kink, and contract said body in area, and removing said causticizing agent from the fibers without substantially stretching said body, thereby fixing the fibers thereof in said intercurled and kinked condition and said body in area-contracted condition.

14. As an article of manufacture, an unwoven fabric of intermingled unspun fibers comprising essentially, and primarily dependent for its integrity upon, frictionally interlocked cleaned cotton

fibers of textile length, said cotton fibers being characterized by artificially-induced irregular kinks, twists, bends and curls, whereby the fibers are held together to form a conformable extensible coherent cotton felt, said felt having an extension of at least thirty percent in at least one dimension.

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