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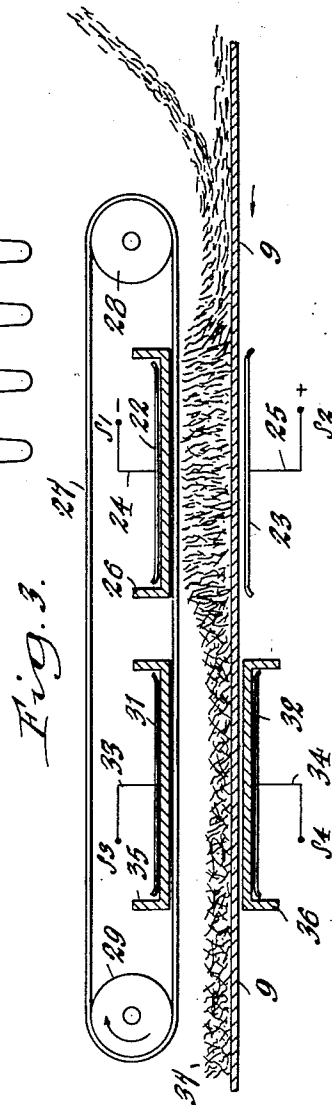
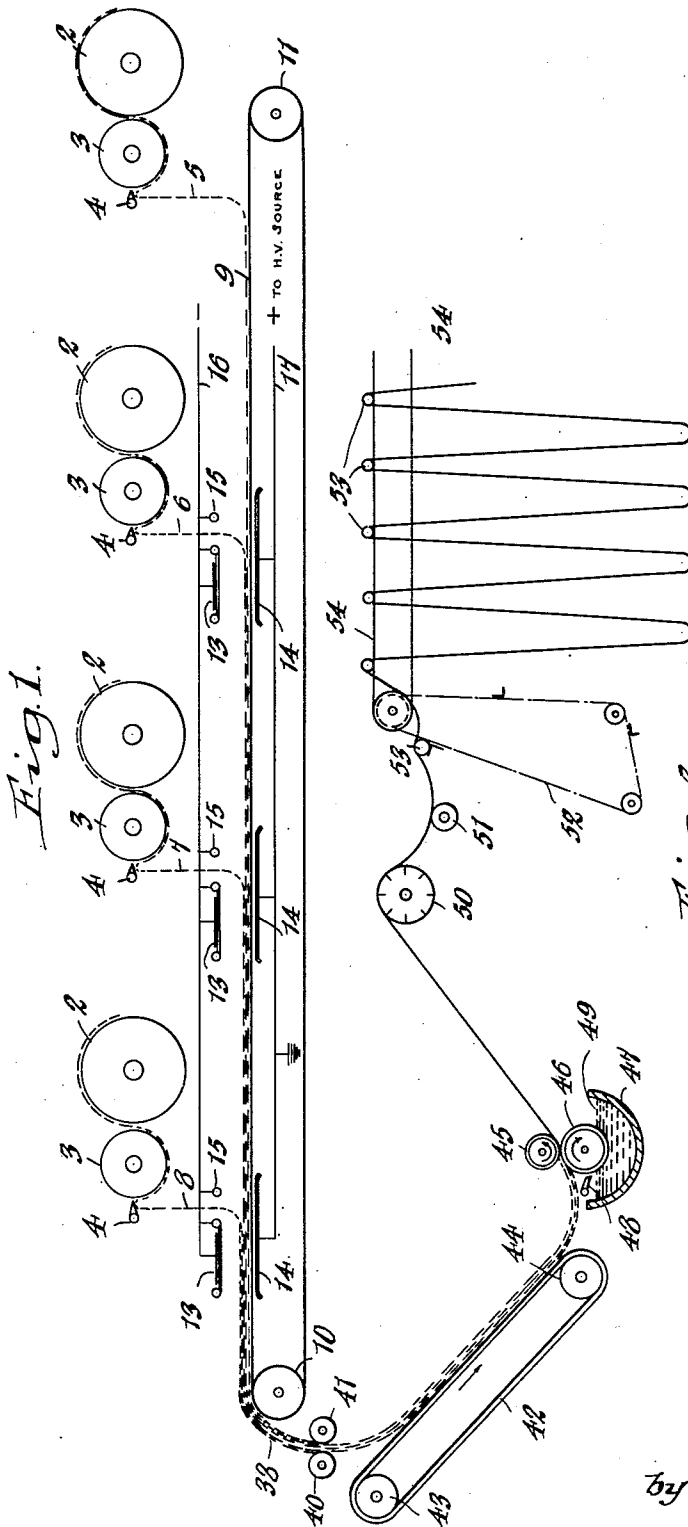
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2,385,873

METHOD OF FORMING WEB MATERIAL

Filed April 18, 1942

2 Sheets-Sheet 1



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*Fig. 2.*

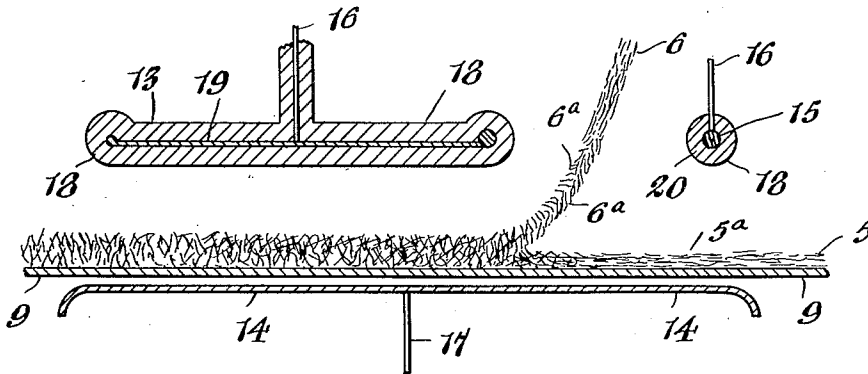
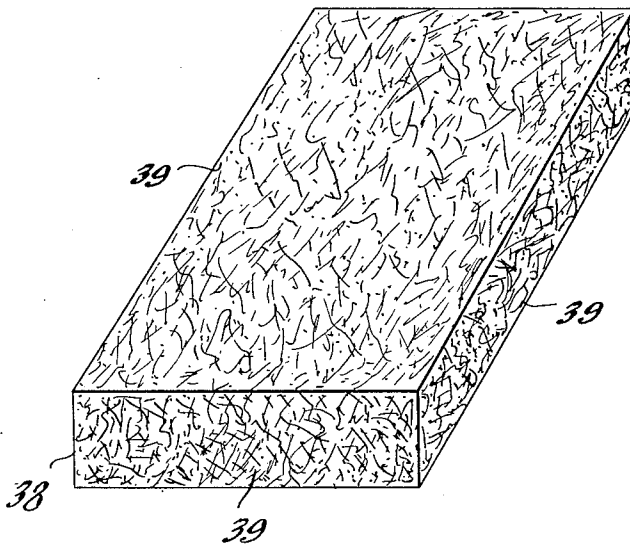


*Fig. 4.*



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## UNITED STATES PATENT OFFICE

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## METHOD OF FORMING WEB MATERIAL

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6 Claims. (Cl. 117-17)

This invention relates to an improved method of manufacturing flexible fibrous webs of non-lamellar felted structure from a plurality of thin carded unwoven membranes, and also relates to apparatus for carrying out said process. More particularly, it is concerned with a method of electrically weaving and interlocking the individual fibres of each of several membranes constituting the web with the fibres of the other membranes by exposing or subjecting the membranes to the influence of electrostatic fields of sufficient strength to electrically charge the fibres and upend them in a manner suitable for intermingling the membranes one with the other to form a non-laminated structure, but of insufficient strength to rupture or harmfully disturb the membrane itself. The invention further relates to the formation of flexible webs in the above manner in which various modifying agents are incorporated in the web to impart specific desired properties to all or portions of the web structure.

The general process heretofore used for making felted fibrous webs from a plurality of thin carded fibrous membranes is best illustrated in the Patent No. 2,055,411 to Edward Hurst. There the weaving and interlocking of the fibres has been attained by the use of currents of air or other gas which are passed through the membranes to disturb the normally horizontal arrangement of the fibres and is referred to therein as an "aerodynamic" weaving action. However, the control of air currents, regardless of how gentle, is at best difficult and subject to surges and fluctuations which interfere with a uniform interweaving action, and at times even cause rupture or non-uniform distribution of the membrane, holding up operation until the condition is corrected or the break repaired. The use of an aerodynamic weaving process also requires a chamber or other substantially enclosed space for passage of the membranes so that an atmospheric or gaseous pressure differential can be maintained from one side of the membrane to the other side and thereby create and promote the necessary weaving action.

An object of the present invention is to provide an improved method and apparatus for weaving and intermingling the individual fibres of such webs by electrostatic means, which process is capable of closer control and otherwise overcomes or obviates the undesirable features of the previously employed aerodynamic methods as will readily become apparent as the description of the present process and apparatus proceeds.

In accordance with the present invention as each thin fibrous membrane is removed from a carding machine it is deposited upon a moving endless support or carrier and passed through an electrostatic field whereupon the individual fibres of the membrane are given an electrical charge

which causes the ends of the fibres to be upended from the horizontal plane of the membrane. While the fibres of the membrane are in such an electrified condition suitable for interlocking, additional fibrous membranes are similarly electrified to upend their respective fibres and in that condition superimposed upon the initially deposited and still electrified membrane whereby the fibres of each membrane, due to their electrical charges, are woven and interlocked with the fibres of adjoining membranes. As a further means to promote a weaving action, and particularly a lateral or patterned weaving, certain of the electrodes which serve to create the electrostatic fields may be positioned or reciprocated laterally so as to give a sidewise orientation or pull to certain of the fibres. Also, the lower electrode of an electrode pair may be formed with a multiplicity of points or of an open grid shape so as to impart a controlled but variable orienting and weaving action to the fibres, and by reason of the pointed projections produce a number of small intense electrical fields which give added penetrating power and vertical weaving together of the fibres of the various membranes.

Moreover, modifying agents such as water-proofing compounds, anti-friction agents, flexibilizers, adhesives and other fillers may be incorporated in the web at the time of making in order to render the web resistant to water or impart other specific desirable properties to all or certain controlled portions of the web.

This invention may be more clearly understood by reference to the accompanying drawings, in which:

Figure 1 is a vertical diagrammatic cross-section of an apparatus for making flexible fibrous webs in accordance with the teachings of the present invention;

Figure 2 is an enlarged vertical cross-section of that portion of the apparatus used for the electrostatic weaving of the fibres and showing one of the electrode pairs in further detail;

Figure 3 is a vertical cross-section of a modified form of the apparatus shown in Figure 2; and

Figure 4 is a perspective view on an exaggerated scale showing a portion of a fibrous web formed by my method and before the web is impregnated.

Referring further to the apparatus shown in Figure 1, the apparatus comprises a plurality of carder assemblies suitably spaced apart and consisting of carding rolls 2, stripper rolls 3 and combs 4 for removing the fibrous carded membranes 5, 6, 7 and 8 from the rolls 3. The carded membranes may consist of any animal, vegetable or synthetic fibrous material capable of being carded into yarn or sheet form. While cotton fibres have proven to be highly satisfactory for

the present process, other fibres suggested for use are such natural fibres as wool, jute, flax and the like, or any of the newer synthetic fibres such as glass wool, resinous or synthetic rubber fibres. Also, instead of having all of the fibres of the same material, one or more of the fibrous membranes may be of a different fibre than the rest. Although only four carder assemblies are shown in Figure 1, any number of carders may be used depending upon the desired thickness and type of fibrous web.

The carded membranes are fed by gravity onto a moving carrier belt 9 which is slightly wider than the width of the deposited membranes and may have upturned or flanged edges for guiding the oncoming membranes onto the moving support. The supporting conveyor belt may be any suitable flexible, electrically non-conducting material, a rubberized fabric belt sold under the trade name "Ton-Tex" being found highly suitable for the purpose. The conveyor belt is supported by the rolls 10 and 11, which are driven by suitable means (not shown), and the speed of the belt synchronized with that of the carded membranes in order that no appreciable strain or pull is exerted on the thin membranes during their deposition.

The initial membrane 5 is deposited directly onto the conveyor belt and then as each successive membrane 6, 7 and 8 is being deposited it is passed through a series of electrostatic fields created between electrodes 13, 14 and 15, which extend the full width of the conveyor 9 and are positioned above and below the moving belt. As the membranes move into the electrostatic field the individual fibres become disarranged and are shifted from their normal parallel position (assumed as a result of the carding operation) so as to assume upright or upended positions. While the loose ends of the individual fibres are in such upstanding position, the membranes are brought together and the individual fibres caused to intertwine and produce a firm homogeneous interlocking structure which will be non-lamellar in final appearance.

An auxiliary or secondary electrode 15 having the same polarity as the electrode 13 is positioned so that the gravity-fed membrane between it and the electrode 13 is approximately equidistant from the two upper electrodes so that the fibres of the membrane are equally repelled from (or drawn to) the two and therefore maintained in equilibrium and guided without disturbance to the carrier belt 9.

The source of electromotive force for creating the electrostatic fields, the effective potential of which is 20,000 volts or more, is not specifically shown in the drawings, but is indicated by the positive (+) and negative (-) symbols and connected to the electrodes 13, 15 and 14 by the connecting lead wires 16 and 17 respectively. The source of electromotive force may produce a continuous unidirectional current, an intermittent unidirectional current, or an alternating current depending upon the particular requirements. The effects of direct current and alternating current electrostatic fields will be described herein after in greater detail. When a unidirectional current source is utilized it is preferable that the upper electrodes 13, 15 be connected to the negative terminal and the lower electrode 14 be connected to the positive terminal. However, if desired, the polarity of the electrodes may be reversed, and as a safety measure it is desirable

that the lower or bare metal electrode be grounded.

Fibres leaving the carder assembly are arranged in a generally parallel position which is normally produced by the carding action. If deposited on the carrier belt in this state the fibres assume for the most part a position substantially parallel to the surface of the belt. With the application of additional fibrous membranes, the several layers would be merely stacked one on the other and a laminated web produced which separates readily. Instead, it is desirable that an interlocking fibrous structure be produced in which most of the fibres of each membrane project upwardly at acute or right angles to the surface of the web and not only intertwine with one another but also interlock and knit together with the fibres of the succeeding superimposed layers. This action is accomplished in an improved manner by the present process employing an electrostatic intermingling action.

The electrostatic means for accomplishing this action is shown in greater detail in Figure 2 of the drawings. The electrically charged electrodes and the particular manner in which they are positioned and used for reception of the fibrous membrane 6 and its juncture with the previously deposited membrane 5 is clearly depicted. The membrane 6 is fed by gravity down and between the upper electrode 13 and the auxiliary electrode 15, both of which are similarly charged with a negative polarity. Electrode 15 cooperates with electrode 13 in imparting an electrostatic charge onto the fibres of the membrane 6 as it is fed therebetween and onto the previously deposited membrane 5. It also serves in conjunction with the rear portion of lower electrode 14 to electrostatically charge and maintain the electrified condition imparted to the previously deposited membrane 5 so that the individual fibres 5a remain substantially upright and ready for interlocking with the upstanding fibres 6a of membrane 6. Thus the electrostatic field set up between the electrodes 13, 14, 15 by application of a high electromotive force thereto serves to orient the outermost fibres of both membranes to an upended position highly suitable for interlocking and meshing together into a well-knit, non-laminated structure having a creditably high strength.

The character and construction of the upper electrodes 13 and 15 are of great importance in the operation of the apparatus and, preferably, are shielded by some "poorly conducting" material. The materials so used should be low enough in conductance that not enough current can flow along or through it to cause arcing between the upper and lower electrodes, yet it should be sufficiently conductive to allow a small leakage current to supply electrical charges to the membrane fibres in order that they may be oriented and raised to an upright position suitable for interlocking with one another. Therefore the upper or high potential electrodes 13 and 15 are formed of a poorly conducting material 18 which completely surrounds the metallic plate 19 of electrode 13 and the metallic rod 20 of electrode 15. In speaking of a poorly conducting material this expression is used to distinguish between such materials as metals, carbon, or the like, which are relatively good conductors of electricity, on the one hand, and highly insulating materials such as hard rubber, varnished cambric or the like, which are such good insulators at the voltage I prefer to apply to my apparatus that the leakage

current which flows through them is insufficient to electrically charge the fibrous membrane, on the other hand. For this purpose I have found molded materials, such as those sold under the trade names of "Micarta" and "Bakelite" to be most satisfactory. However, other materials such as dry, knot-free wood can also be used. While these materials are so poorly conducting that they will not carry enough current to permit "spark over" or arcing between the upper and lower electrodes, they are sufficiently conductive at the voltages employed to allow enough leakage current to pass and supply the small amount of electrostatic charges required.

Ordinarily the lower electrode 14 is at ground potential and thus does not need to be encased by a poorly conducting sheath.

Figure 3 illustrates a modified form of electrostatic apparatus for intermingling and weaving the individual fibres of successively deposited fibrous membranes to form a unified web structure. This apparatus differs from that shown in Figures 1 and 2 in that an upper carrier belt is provided as well as two separate and distinct electrostatic fields so that the fibrous material may be subjected to the effects of both a unidirectional electrostatic field and a pulsating or alternating current field. In this particular apparatus the carded membrane 6 is fed by gravity onto a previously deposited membrane 5 carried by the conveyor belt 9 and the superposed membranes moved into a unidirectional electrostatic field established between the electrode members 22 and 23. This unidirectional electrostatic field is produced by a source of electromotive force, the effective potential of which is 20,000 volts, or more, not specifically shown in the drawings, but indicated by the reference characters S1 and S2. Ordinarily the upper electrode 22 is connected to the negative terminal S1 of the source of high voltage by the connecting wire 24 and the lower electrode 23 is connected to the positive terminal S2 of the connector 25. However, the polarity of the electrodes may be reversed when so desired. A body of poorly conducting material 26 is interposed between the high tension electrodes 22 and 23 so as to prevent electrical flash-over or arcing therebetween.

As the membrane 5 and superposed membrane 6 move into the unidirectional electrostatic field the individual fibres of each membrane become electrically charged and caused to become oriented or upended from their normal positions. There is also a translational force produced by the action of the electrostatic field on the charged fibres which causes these individual fibres to tend to move toward the electrode of opposite polarity and distend the thickness of the superposed membranes. Thus the air gap between the electrodes may in some cases be practically filled by the fibres of the extended membranes. Also, the upended ends of the fibres of both membranes intertwine and interlock to such an extent that membranes 5 and 6 become unified and indistinguishable.

A carrier belt 27, mounted on supporting rolls 28, 29, is driven synchronously with the conveyor belt 9, by suitable means (not shown) and assists in moving the distended membranes through the unidirectional electrostatic field and into the adjoining alternating current field where the distended fibrous web is caused to collapse. This adjoining field of alternating polarity is established between the electrode members 31, 32, by a source of high voltage alternating current, the

effective potential of which is 20,000 volts, or more, not specifically shown in the drawings but indicated by the reference symbols S3 and S4. This source of alternating or pulsating current is connected to the electrode members 31, 32, by means of electrical cables 33 and 34, respectively. Channel members 35 and 36, of poorly conducting material, shield the electrode members 31 and 32 and prevent sparking or electrical flash-over therebetween.

As the fibrous membranes pass from the unidirectional electrostatic field into the closely adjoining field of alternating polarity, the distended fibrous structure is agitated by the action of the alternating electrostatic field and the individual fibres caused to become more firmly entwined one with another and interwoven or felted. The entire web, as well as the individual fibres, is agitated by the action of the alternating field to such a degree that a partial consolidation of the distended fibrous structure occurs as the material passes through this electrical field. Upon leaving the zone of electrical treatment the several membranes, which make up the web structure 37, are found to be felted together forming a unified web structure which does not delaminate readily.

The apparatus illustrated in Figure 3 may replace each of the electrostatic units shown in Figure 1 or, if desired, one such unit may be located at the delivery end of the conveyor belt 9 and the several fibrous membranes 5, 6, 7 and 8 electrically felted in one single operation.

After the fibrous web has been built up to the required thickness and electrically treated in the manner described it is ready to be consolidated to a greater density for added strength. At the same time it is desirable to incorporate a liquid adhesive binder within said web to bond the compacted fibres and produce a web of greater density having a strength comparable to that of cloth.

The electrically woven fibrous web 38 moves from the terminus of the conveyor 9 and passes between synchronously driven rolls 40, 41, where it is initially compacted. Passing from these compacting rolls the web is fed onto a moving conveyor belt 42, which is supported by the synchronously driven rolls 43, 44, and delivered to the adhesive binder applying rolls 45, 46. The liquid adhesive binder is contained in a pan 47, which may be water-jacketed and heated as required. Lower roll 46 is partially immersed in the liquid adhesive 49 and as it revolves a quantity of adhesive binder, determined by the adjustably spaced scraper bar 48, is applied into the web. Upper roll 45 is adjustably spaced with respect to the adhesive roll 46 and applies sufficient pressure to finally compact the loose fibrous web as well as aid in forcing the binder to permeate into and throughout the web structure. The surfaces of both rolls 45 and 46 should be covered with a resilient layer of absorbing material.

The adhesive binder used to permeate and assist in maintaining the consolidated condition of the web is preferably one of a flexible or resilient nature, such as latex, flexibilized animal or vegetable glue, plasticized vinyl resin, plasticized urea formaldehyde resin, and the like. Such flexible adhesives permit the retention of the natural pliable character of the interlocked fibrous structure.

After the web is compacted and the proper amount of adhesive binder applied therethrough, it is passed over a suction drum 50 and idler roll 51 to a suitable chamber where it is dried or cured. This chamber contains an endless con-

veyor 52 which serves to festoon the web onto supporting sticks 53 and to transport these sticks and looped material to the moving rack 54. The speed of the moving rack 54 is so adjusted that the adhesive binder is properly set or cured by the time it reaches the end of the chamber. When the web material is taken down from the drying rack it is wound up into rolls or cut into sheets suitable for sale.

Figure 4 is a greatly enlarged perspective view of a piece of fibrous web 38 made by electrically interweaving and felting several fibrous membranes as described above. This illustration shows roughly the arrangement of the individual fibres 39 within the web structure. They are so interwoven or interlocked as to form the equivalent of a woven fabric and the heterogeneous arrangement of the individual fibres extends in a multiplicity of non-parallel planes throughout the web structure. Since there is no discernible line of demarcation between the several membranes which make up the web 38 there is no tendency for the web to delaminate during use.

A modification of the present invention provides for the production of fibrous webs of great tensile strength and resistance to crosswise tearing for use under very severe conditions. Mechanical reinforcing means, of metallic or non-metallic nature, can be built into the web in the course of its construction. For example, spaced strands of cotton thread, string, synthetic resinous filaments or fine diameter wire can be introduced onto the carded layers of fabric as the web is being formed. Spools of the stranded materials may be mounted on a suitable framework (not shown) and the reinforcing material fed into the deposited membrane as the web is built up by the apparatus shown in Figure 1. The inclusion of the reinforcing strands may be uniform throughout the web structure or it may be limited to the insertion of a single layer of reinforcing fabric or thread positioned at the most advantageous point in the web. A wave form type of reinforcement is produced by oscillating the framework which carries the spools or reels of stranded material.

As is apparent from the above description of the electro-static method of forming felted fibrous webs, there are numerous advantages over the prior art in addition to those already recited. By the use of patterned or grid-like electrodes it is possible to provide a patterned or variable weaving unattainable by dependence upon air currents for any weaving action. Also, the present process permits of close control over each and all of the electro-static fields separately or cooperatively as desired; for example, the strength of the fields may be varied depending upon the thickness of the membranous layers deposited, and closely maintained so as to avoid damage or disturbance to the membranes before deposition. Also, lateral weaving of the fibres can be easily accomplished by positioning electrodes at the sides or by a vibration or sideways movement of the upper and/or lower electrodes of all or any particular electrode pair.

While the preferred embodiment of the invention has been specifically illustrated and described, it is to be understood that the invention may be otherwise embodied and practiced within the scope of the appended claims.

I claim:

1. The method of manufacturing flexible fibrous webs of non-lamellar structure which comprises feeding a plurality of carded fibrous membranes

from carding cylinders onto a moving endless support, passing said carded fibrous membranes through an electrostatic field after removal from the carding cylinders whereby the individual fibres of each fibrous membrane are electrically charged and brought into interlocking position with the fibres of adjoining membranes without disruption of the membranous structure, compacting the resulting fibrous web and removing it from said support.

2. In the process of making flexible fibrous webs having a non-lamellar structure from a plurality of superimposed carded fibrous membranes of unwoven nature the step which comprises passing the individual membranes through an electrostatic field after removal from the carding cylinders to impart an electrical charge to the individual fibres thereof and cause an intermingling and weaving together of the fibres of one membrane with the fibres of adjoining membranes without disruption of the membranous structure.

3. The method of manufacturing flexible fibrous webs of non-lamellar structure which comprises feeding a carded fibrous membrane upon a moving endless support, exposing said membrane to the influence of an electrostatic field to impart an electrical charge to the individual fibres and bring about a raising of the ends thereof, superimposing similar fibrous membranes upon the upended fibres of the originally deposited membrane so that the fibres of the two commingle, repeating the aforementioned steps until a web of the desired thickness is obtained, compacting the web and removing it from said support.

4. The method of manufacturing flexible fibrous webs of non-lamellar structure which comprises feeding a plurality of carded fibrous membranes from carding cylinders onto a moving endless support, passing said carded fibrous membranes through an electrostatic field after removal from the carding cylinders whereby the individual fibres of each fibrous membrane are electrically charged and brought into interlocking position with the fibres of adjoining membranes without disruption of the membranous structure, adding a flexibilized adhesive binder to the web, compacting the web and removing it from said support.

5. The method of manufacturing flexible fibrous webs of non-lamellar structure which comprises feeding a plurality of carded fibrous membranes from carding cylinders onto a moving endless support, passing said carded fibrous membranes through an electrostatic field after removal from the carding cylinders whereby the individual fibres of each fibrous membrane are electrically charged and brought into position for interlocking with the fibres of adjoining membranes without disruption of the membranous structure, applying an adhesive binder to the web, compacting the web and removing it from said support.

6. In the process of making flexible fibrous webs having a non-lamellar structure from a plurality of superimposed carded fibrous membranes of unwoven nature, the steps which comprise passing the individual membranes through a unidirectional electrostatic field to impart an electrical charge to the individual fibres thereof and distend the fibrous membranes by upending and agitating the individual fibres thereof and then passing the distended fibrous membranes through an alternating current electrostatic field to cause an intermingling and interweaving of the still electrified fibres of one membrane with the fibres of adjoining membranes.

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