Dec. 11, 1951 T. L. LYNAM 2,577,784

METHOD AND APPARATUS FOR MAKING FIBROUS SHEET MATERIAL

Filed Feb. 7, 1946 3 Sheets-Sheet 1

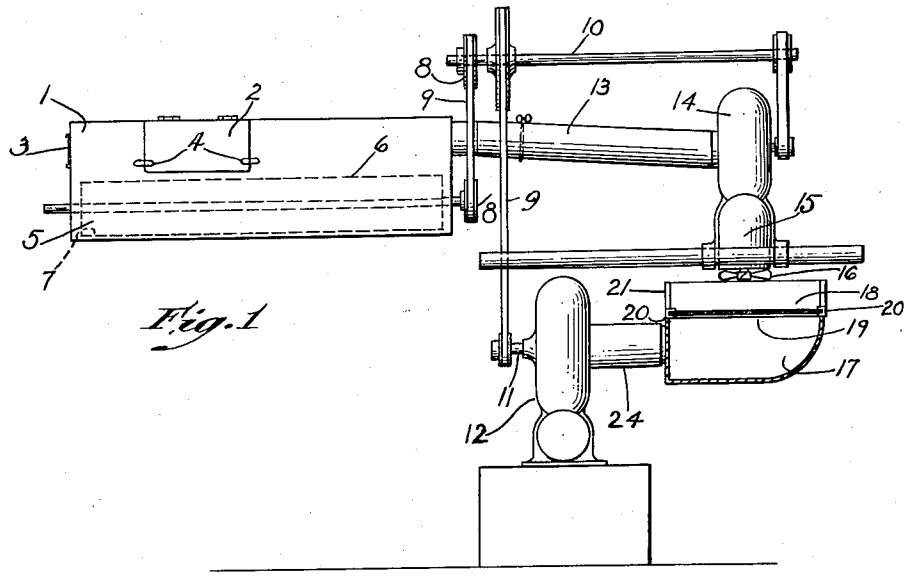


Fig. 1

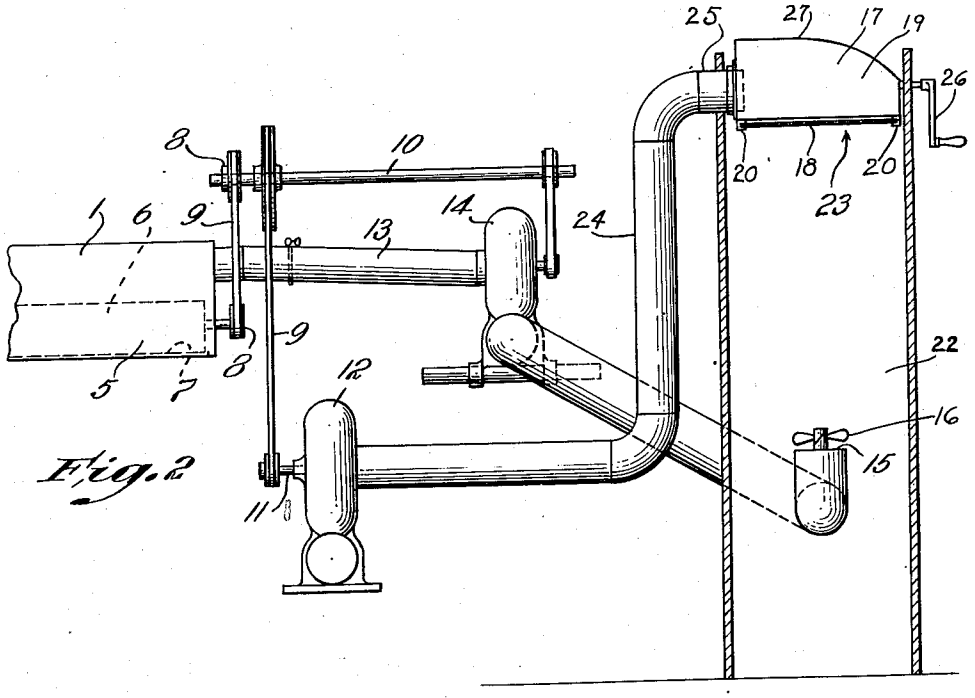


Fig. 2

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Filed Feb. 7, 1946 3 Sheets-Sheet 2

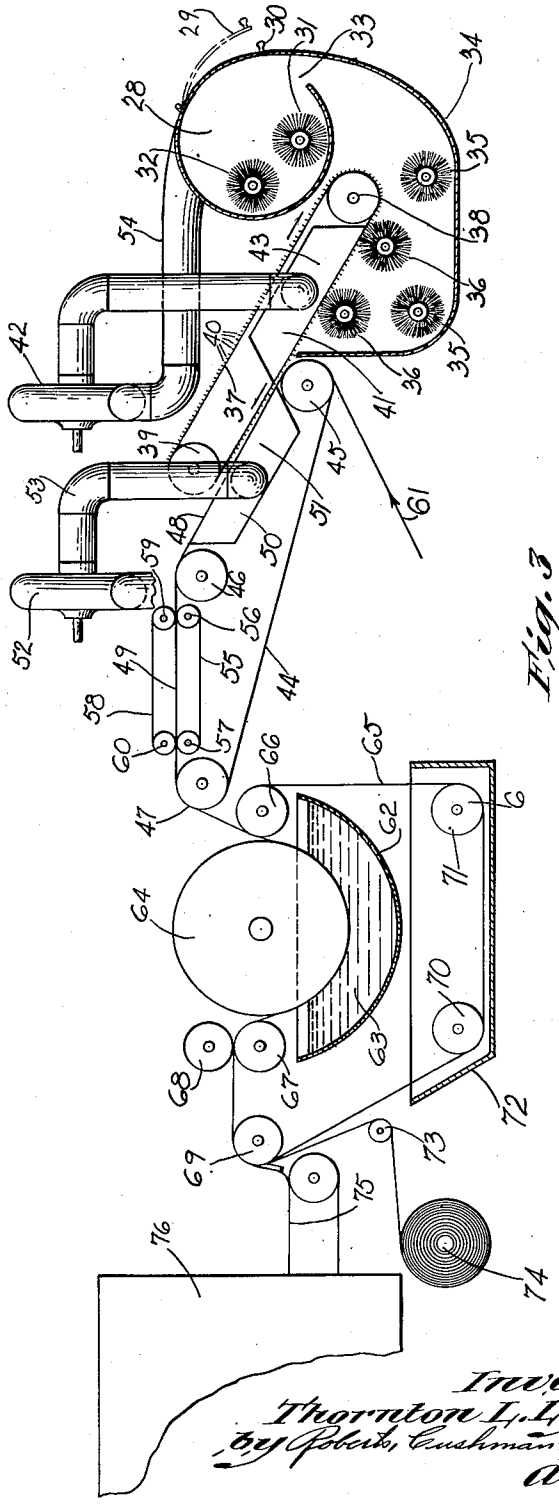


Fig. 3

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Filed Feb. 7, 1946 3 Sheets-Sheet 3

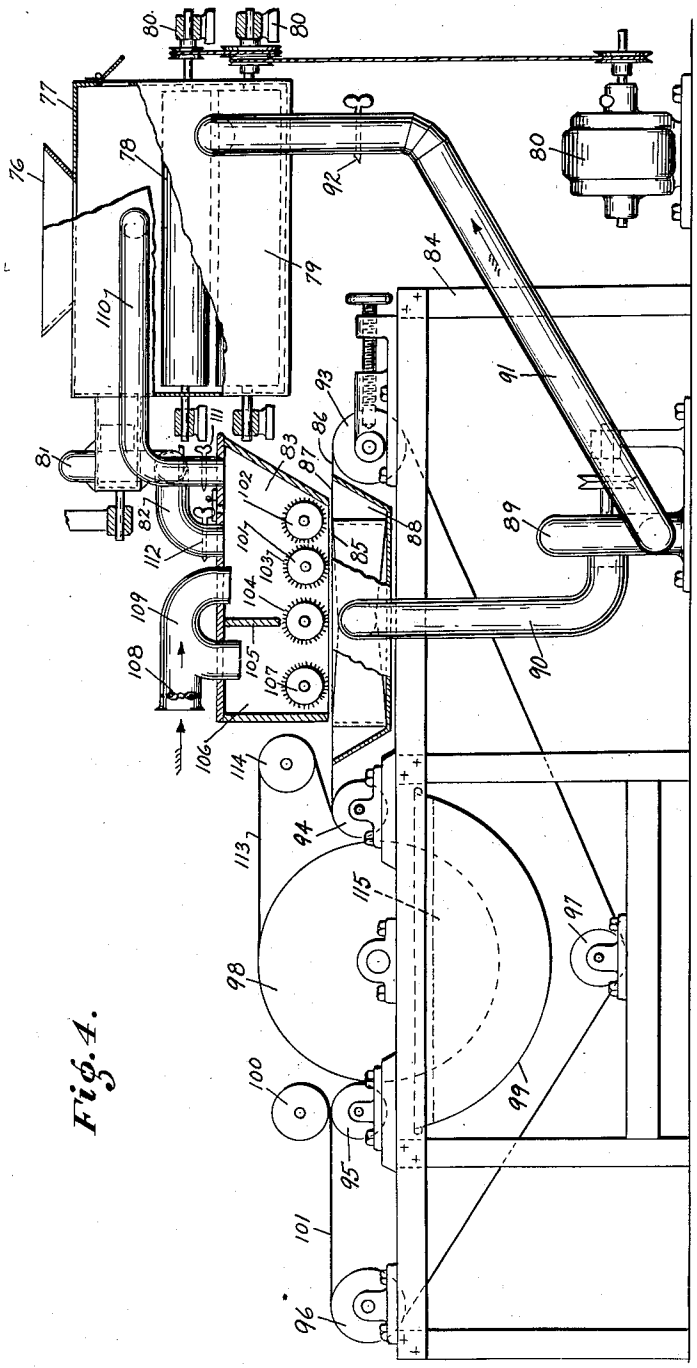


Fig. 4.

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UNITED STATES PATENT OFFICE

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METHOD AND APPARATUS FOR MAKING FIBROUS SHEET MATERIAL

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Application February 7, 1946, Serial No. 646,139

2 Claims. (Cl. 154—29)

1

This invention relates to a method of manipulating and aggregating fibers, and more especially leather fibers, into a completely random arrangement or accidental distribution with respect to each other, and stabilizing or rendering such aggregation of the fibers permanent, and to the resulting products.

In the fabrication of shaped articles from fibers in accordance with the procedures of the prior art, the preparation and shaping operations have always been attended by an inherent orientation of the component fibers, in one or two directions or dimensions.

An exception, not in the arts but in nature, is found in the normal growth of animal hides, and the subsequent manifestation of such growth in the fibrous structure of leathers made therefrom. In leather, the fibrous structure is characterized by a nearly random arrangement of the fibrous components of the leather in all directions, that is both laterally and longitudinally throughout the area of the leather and to some extent, though not fully so, from one surface of the hide to the other. In consequence of this structural feature, leather is often declared and, in fact, found in actual practice to have no completely adequate substitute.

It is an object of the present invention to provide a method of and means for manipulating fibrous materials in such a way as to effect a completely random arrangement of the fibers with respect to each other, in all three dimensions or directions, and to aggregate the fibers of such random dispersion into a desired shape or sheet and to stabilize or render permanent such aggregation, either by means of the fibers themselves or by supplementary binding means or materials. It is also an object to provide fibrous, shaped, or sheeted products which shall possess the characteristic fiber structure of leather made directly from animal hides (or a more complete realization thereof), and numerous modifications and derivatives of such products which are thus made possible. Other objects will appear from the following dsclosure and claims.

In accordance with the present invention it is found that fibers, in order to be manipulated and controlled must be dry or at least superficially dry. The surface tension and other characteristics of liquids, either between, around or upon the fibers, such as liquid columns, drops, or films (or even when adsorbed on the fiber surfaces), are so great as to impede or prevent any adequate control of the manipulation of the

2

fibers to a desired and definite result. The forces involved by the presence and contact phenomena of liquids are so great as to invariably to result in an orientation of the fibers, especially longitudinally of the fibers and in at least one dimension or direction of the mass, before it is finally formed or shaped.

It is also found that even fibers having dry surfaces, when in contact with each other, present numerous solid surface characteristics which likewise may prevent adequate manipulation of them to any specifically desired shape or conformation without residual characteristics of the manipulations being imposed upon them, or imparted to the resulting mass or product. Among such surface characteristics of dry fibers may be more particularly mentioned those of friction, adsorption, and mutual attraction and repulsion. All of these are great relative to the mass and volume of the individual fibers. They are not completely overcome or dispelled, because they are inherent in the fibrous character itself.

It is found, however, in accordance with the present invention that if fibers are prepared in dry, or superficially dry condition, they may be dispersed in a gaseous medium, and into a spaced independent relationship which is completely free from contact with or influence by one upon another. It is also found that in such gaseous dispersion of the fibers, the individual fibers may be given a completely random arrangement of distribution throughout the volume or space occupied by the dispersion, with respect to each other and in all directions, that is in all three dimensions of such space. Moreover, it is now further found that the resulting dispersion may be made to conform to any shape and furthermore that if the relative movement of the fibers be arrested abruptly, as by sudden reduction of its volume, the random dispersion and arrangement of the fiber components will be retained. Thus, the volume and shaped of such gaseous dispersion of fibers may be reduced and the fibers condensed and aggregated without loss of such dispersed relationship (though of increased concentration) and brought into increased, independently inter related mutual contacts with each other, without orientation of the same in any dimension or direction. The random arrangement of the dispersion of such free mutually independent fibers may be thus aggregated and stabilized by the contacts between them and by the increased density of the structural arrangement thus formed of, by and between the fibers themselves. The gaseous dispersing medium

may be removed concomitantly with the reduction of volume, without affecting such characteristic structure, formed of the fibers. The resulting volume or shape occupied by the fibers will be thus rendered of successively increasing consistency, capable of acquiring self-retaining and self-sustaining properties. Moreover, the shaped and aggregated fiber mass may be rendered permanent, by further modification or development of the association between the individual fibers throughout the mass, either per se or inter se, by appropriate bonding means or materials and at any selected stages or degree of aggregation.

As a result of such reduction in the space occupied or densification of the dispersed fibers while in random arrangement and without loss of such random arrangement or orientation of the fibers in any direction or dimension, the fiber dispersion or fiber mass may be manipulated as a whole substantially to such shapes and over all dimensions as may be desired. It still maintains in the resulting product this characteristic structure or random arrangement of its component fibers in three dimensions throughout the various degrees of apparent density imposed, and even to the production of a continuous solid compact fibrous body.

One concept of such transition from a dilute dispersion of free, independent fibers, in a large volume of air as the suspending medium, to a density in which the fibers come into frequent contact with each other and then into a mutually restraining and retaining contact relationship, such that subsequent relative movement and orientation are prevented, followed by such further compacting as may be desired, is that of maintaining the dispersion by agitation of the dispersing gaseous medium, and concomitantly abruptly reducing the entire volume in which the air and fibers are dispersed. This will result in an increasing concentration of the fiber-space relationship and an increase in the pressure of the gas and density of the gaseous medium and of the charge as a whole. At or beyond the point of reduction in volume, concentration or densification at which the mean free path of the fibers is intercepted, so that the fibers come into random contacts with each other, and further relative movement between the fibers is thus impeded, the gaseous medium can be allowed to escape (or even evacuated) without disturbing the relationship of the dimensional, accidental or random arrangement of the fibers, and to such further degree of density as may be desired or required for any particular purpose.

With or without actual removal of the dispersing gaseous medium from between the contacting fibers (even to the degree of imposing sub-normal pressure or vacuum, for example) the self-sustaining contact relationships between the fibers will be such as to permit the application of appropriate conditions or the introduction of gases, liquids or solids into the remaining interstices between the fibers (immediately before, during or after their mutual contacting association or aggregation) to develop or effect binding action therebetween, without dimensional orientation of the fibers. Consequently the characteristic three-dimensional structure of the resulting mass as thus originally created will be maintained, developed and preserved through subsequent shaping operations or the like and be rendered permanent and thus preserved in the fibrous mass and in products made therefrom.

The reduction in volume of the gaseous dispersion of fibers if effected abruptly or suddenly throughout the affected volume of the dispersion may be effected in all three directions or dimensions, or in two dimensions or in one dimension only, with like results of preserving the random arrangement of the fibers. Of these three, the reduction in volume in one direction is usually the simplest and most convenient to effect in practice. But in all three cases, the reduction in volume is best and in fact necessarily, effected as quickly or as suddenly as practicable from the stage of free, independent movement of the dispersed fibers to that of direct contact (i. e., substantially continuous sequences of direct contacts) between the fibers throughout the mass or charge, thus quickly and abruptly arresting and preventing any substantial degree of subsequent free relative movement between the fibers in any direction. By this sudden change the completely random arrangement of the dispersed free and independent fibers is arrested and stabilized, in status quo. Free manipulation of the volume, shape and size of the suspended mass of fibers up to this point is possible, without orientation, by virtue of the fact that each fiber is free to move in all three dimensions, independently of the presence of all of the other fibers in the gaseous dispersion medium. After this point of condensation or densification of the dispersed fibers none is free to move per se, in any dimension relative to any of the fibers adjacent to and in contact with it, except against a commensurate, increasing and opposite force of resistance to such movement. Hence the mass can be further compressed, and uneven relative displacement, flow, or densification will not occur. The mass or charge of fibers will expand somewhat or contract under changes of pressure. But it will act substantially as an integrated unitary mass or body of fibers, capable of receiving, transmitting, yielding, or resisting forces imposed upon it as a whole, in contrast to selective action and effect upon specific fibers or portions of them when forces are exerted upon it.

A typical and representative example of the invention will be described with respect to its preferred application to the manipulation and aggregation of leather fibers by a one-dimensional reduction of a free fiber-in-air dispersion, into the form of a sheet, and with reference to the apparatus as shown in the accompanying drawings, in which

Fig. 1 is a front elevation of apparatus suitable for the making of single masses or sheets of leather fibers;

Fig. 2 is a front elevation of a modification of the apparatus shown in Fig. 1;

Fig. 3 is a front elevation of apparatus for the making of continuous masses or sheets from leather fibers; and

Fig. 4 is a front elevation of a further modification and development of the apparatus shown in Fig. 3.

In accordance with the invention leather fibers are prepared by disintegrating leather, usually in the form of waste leather products, though preferably free or freed from coatings, sizings or other contaminant materials (or liberated therefrom after disintegration) to a loose, separated condition of the individual fibers. Leather dust is not harmful, but is not materially helpful in large quantities for the production of a satisfactory product in comparison with clean fibers and may be advantageously removed. The same

may be said of heavy non-fibrous components. The fibers are preferably as long as may be convenient to handle and severally separate from and independent of each other. This may be effected by grinding clean scrap leather in customary apparatus used for the purpose. Extra quantities of dust or other fine solids or impurities if present may be removed if necessary by screening or dusting, washing or like treatment, followed by drying.

The resulting separated, loose leather fibers, as thus obtained, and in dry, or at least superficially dry condition, constitute a very suitable raw material for the purposes of the present invention. In shipment or storage they may become somewhat compacted. They may gather together somewhat to form irregular clumps or nodules. This is not desirable, but does not seriously affect their suitability for the present process. They may become moist or wet, but this may be overcome by drying out. But they should not be wet, either by saturation or superficially, as they enter into the present process of treatment, and they should not be unduly contaminated by fine solids such as leather dust, fillers, finishes, coatings or other non-fibrous extraneous matter, especially if it be heavy, sticky, or combined with the fibers in such a way as to detract from their inherently free fibrous characteristics of being long, slender, and as in the case of leather fibers, preferably rough, irregular, and clinging or fuzzy on their surfaces.

In proceeding in accordance with the invention, such disintegrated, loose, leather fibers may be charged into the disintegrator 1, as shown in Fig. 1, in the form of a horizontal cylindrical drum. This may be effected through the hinged door 2, in the side of the drum or through the door 3, in the end of the drum. The side door 2, may be closed and fastened by clamps 4, while the end door 3 may be left open or otherwise regulated to admit air during the dispersing operation of the disintegrator, as will be more fully described hereafter.

The disintegration effected upon the raw ground leather fibers is largely if not entirely that of completely separating separable or previously separated independent discrete fibers, which may have been rolled together or matted by subsequent handling, etc. This is effected by a cylindrical brush 5, mounted longitudinally within the disintegrator drum, the long stiff bristles 6 of which reach substantially to or contact with the inner surface of the drum, preferably at or near the bottom, or against slightly raised baffle plates 7 thereon. The brush 5 is rotated at a high rate of speed, for example 1200 revolutions or more per minute, by suitable connection through pulleys 8, belts 9 and shaft 10, which is in turn driven by the shaft 11 of the motor 12.

The leather fibers may be simply shovelled into the disintegrator drum through the door 2 in batches. However, they may advantageously be fed regularly into the disintegrator drum automatically and continuously by any appropriate form of conveyor device (not shown) if desired. The bristles 6 of the rotary brush 5 will in either case carry the fibers down and against the bottom of the drum, or plate 7 thereon, and upon being released from their contact with the drum or plate the bristles grip the fibers and clumps of fibers and tear the fibers apart and separate and fling the individual independent fibers up into the air space of the drum above the brush. In this way the fibers are separated and dispersed into and throughout the air of the drum in a free dispersion. In the resulting air and fiber mixture the fibers are severally and completely independent, and suspended in the air, out of contact with each other. They are dispersed beyond their mean free paths of movement and hence each is beyond and outside of the influence of the presence of the other, except for very occasional and non-significant contact or collision. The rapid movement of the brush, the free fibers, and the air, which disperses and suspends the free fibers therein, effects a completely random arrangement of the fibers with respect to each other and the agitation of the air suspends and maintains them in that relationship to each other.

This relatively dilute dispersion and suspension of free fibers in air is susceptible of displacement as a whole, without orientation of the fibers. Accordingly it will tend to expand and pass out of the disintegrator through educt pipe 13 if air is allowed to enter by cracking the door 3. Moreover, such displacement may be effected at a high rate of speed by providing a fan 14 (at the end of the educt pipe 13) which is driven from shaft 10. If the fan 14 is driven at a high rate of speed, the free, independent fibers dispersed in the air are displaced therewith, without friction between themselves or the sides of the educt pipe 13, or other selective movement, inter se, so that no substantial orientation of the fibers lengthwise of their path of movement or otherwise occurs.

The fan 14 delivers the air-suspended dispersion of fibers downwardly through its discharge opening 15. A propeller blade 16 or like distributing device (to counteract any tendency of more rapid flow of fluids at the center of a stream) is provided in the opening 15. It may be positively rotated or driven, but is preferably rotated by the effluent from the fan. This also tends to expand the volume of the suspension laterally and thus to give a greater effective cross-sectional area of the fiber-in-air suspension.

The opening 15 is directed downwardly upon a suction box 17, operated by a powerful suction fan on the shaft of motor 12 and having a horizontal screen 18 mounted to cover its upwardly disposed opening 19. The screen 18 is slidably mounted in grooves 20 so that it may be moved across the opening 19 without breaking its marginal sealing effect upon the suction box opening 19. A square frame 21 or complete enclosure may be placed above this screen, especially when the device is in operation, to confine the air suspension of fibers as it comes from the opening 15, in case the suction is not maintained or the distributor 16 is operating faster (momentarily) than the downward speed of the fiber suspension. Normally, however, the positive downward movement and pressure of the suspending and dispersing air column (with its airborne fibers, in unison therewith) and the negative suction of the suction box downwardly through the screen maintains the movement of the fibers and of the air, as a unit, in a substantially static dispersion equilibrium.

But upon coming immediately above and thence into contact with the screen 18, the fiber-in-air suspension is abruptly and positively arrested and condensed, and the fibers, in their three-dimensional random arrangement with respect to each other are contacted and aggregated upon the screen, while the dispersing and suspending column of air passes on, uniformly, throughout the area of the screen. The dispersion of independent and free fibers is thus con-

centrated and reduced in volume to such an extent, that they come into contact with each other simultaneously, in status quo, and are arrested by actual resistance of their mutual contacts from further movement relative to each other. The accumulation of fibers as thus condensed from dispersion and suspension in air into a randomly dispersed inter-contacting mass of fibers on the screen may be built up to a mass of layers of any desired thickness, yet still characterized by the completely random arrangement of the individual fibers in all three dimensions, in which they were related while in dispersion and suspension in air. But due to their mutual contacts, resistances of friction, and resilience, they now have no free degree of movement relative to each other, to the screen or to the retaining frame. The mass of fibers is therefore effectively aggregated in the shape and dimensions of the frame and integrated into a unit which may be subsequently handled and treated as such, free from subsequent relative displacement and/or orientation of its component fibers.

When the aggregated mass of fibers on the screen has reached a desired thickness, the screen may be removed or it may be advanced longitudinally of the grooves **20** over the suction opening **19** and beneath the frame **21**, thus to present a fresh section of the screen, while simultaneously withdrawing a portion or all of the fibrous layer already formed, at right angles to the direction of accumulation and hence without interruption of subsequent formation.

Another form of the apparatus is shown in Fig. 2 in which like numerals indicate like parts, corresponding to those described and shown in Fig. 1. But in this arrangement the educt pipe is inclined downwardly and with its opening **15** directed upwardly, the propeller blade **16** being mounted above the opening.

Moreover, the opening **15** and propeller blade **16** are mounted within the lower portion of a tower **22** which completely surrounds both. Closing the top of the tower **23** is the suction box **17** which is suitably connected to the suction fan or motor **12** by pipe **24**. Between the suction box **17** and pipe **24** is provided a horizontal collar connection **25** on which the suction box **17** may be rotated by means of the crank **26**. Thus while the opening **19** of the suction box faces downwardly into the tower **22** with a screen **18** slidably mounted thereon in the slide grooves **20**, as shown, it may be quickly rotated outwardly from this position in the tower and into an upwardly facing position from which the layer of aggregated fibers thereon (and thus upwardly disposed) may be removed without breaking the suction or permitting the fibers to become dislodged or disarranged. The rounded bottom **27** suitably fitting the top of the tower **22**, in such rotation, preserves the (hermetically closed) seal between the two.

In this modification of the apparatus extremely fine leather particles, dust, or heavy pieces and impurities may be caused or permitted to separate out from the fibers and to fall by gravity into the bottom of the tower **22**, thus leaving a cleaner and lighter, more buoyant fiber and air or suspension mixture to be displaced upwardly as a whole and aggregated against the screen **18**.

A continuous displacement of fibers and aggregation of them as a continuous mass or sheet formation may be accomplished by the apparatus shown in Fig. 3.

In this apparatus the raw fibrous material is

fed into the disintegrator **28**, through the door **29**, which may be closed and fastened by the latch **30**. Alternatively, a continuous automatically controlled and regulated input or feed of fibrous material thereto, may be made if desired, by suitable well known constant feed or stoker apparatus, not shown. The disintegrator **28** is in the form of a substantially cylindrical drum having two cylindrical brushes **31**, **32** mounted longitudinally thereof. The bristles on the lower brush come into contact with the bottom of the drum while the bristles of the upper brush may or may not contact the inside of the drum, or more lightly than the lower brush, as desired. Slightly above the bottom portion of the drum and opposite the lower brush an opening **33** is provided tangential with the walls of the drum, leading into a duct or conduit **34**.

Near to or with their bristles in contact with the bottom of the duct **34** are mounted two cylindrical rotated brushes **35**, **35**.

Mounted within and also leading out from the upper portion of the duct **34** is provided a perforated or endless belt or screen **37** passing over suitably driven pulleys **38**, **39** in an upwardly inclined direction, as shown, and having a great plurality of shaped and finely pointed pins **40** projecting perpendicularly from the belt and preferably in closely spaced relationship throughout its outer surface. Within the portion of the space traversed by the belt while within the duct **34** and slightly beyond is provided a suction box **41** in which suction is provided and maintained by the suction fan **42**. The opening **43** of the suction box registers with the inner, smooth surface of the belt **37** and is hermetically sealed thereto around its margins.

A pair of brushes **36**, **36** are also mounted in the duct **34** beneath the under course of the belt **37** for driven rotation in a direction opposite to the travel of the belt and spaced therefrom just sufficiently to clear the tops of the pointed pins **40** on the belt. The bristles (or needles) of the first or lower brush may clear the tops of the pins and the bristles on the second or upper brush may pass slightly beyond the tips of the pins **40**.

The portion of the endless belt **37** which extends out of and beyond the duct **34** also extends beyond the opening **43** of the suction box. Mounted beneath this under portion of the belt **37** and adjacent thereto but at a diverging angle is provided a plain endless perforated belt or screen **44** trained over pulleys **45**, **46** and **47**. Between the pulleys **45** and **46** the belt **44** forms an incline **48** passing beneath and in the same general direction as the belt **37** but gradually diverging therefrom and thence onto a horizontal pass **49** between the pulleys **46** and **47**.

Mounted beneath the inclined portion **48** of the belt **44** is provided a suction box **50** having an upwardly disposed opening **51** in registry with and hermetically sealed to the under side of the belt **44**. The suction box **50** is actuated by a suction fan **52** through pipe **53**.

In operation the fibrous material such as the separated fibers of ground scrap leather are charged or continuously delivered into the disintegrator drum **28**. If the charging is intermittent, the door **29** is thereafter closed and fastened. If the feed is continuous, the entrance is closed sufficiently to avoid excessive intake or expulsion of air. The brushes **31**, **32** will be rotated at a high speed in the direction of the arrows by any suitable power means (not shown). The suction fan **42** is also operated at high speed,

the air therefrom being led back into the disintegrator through the air duct 54. The air duct from fan 52 may also be led back into the disintegrator drum 28 or discharged into the atmosphere as desired.

The fibrous material is disintegrated by the brushes, separated, and the separated individual fibers completely and uniformly dispersed into the air of the disintegrator drum, in dilute fiber-in-air suspension therein, and the mixture of air and fibers thus formed is continuously displaced, moving out through opening 33 into the duct 34. Here it is again agitated by brushes 35 and the random dispersion of fibers fills the entire space. As it passes up against the under side of the screen belt 37, it is suddenly arrested by the suction, the fibers being aggregated on the screen belt in their dispersed random relationship and remaining in situ on the belt while the suspending air passes therethrough and off through the suction box 41.

By traversing the belt 37 in the direction of the arrows, through pulleys 38 and 39, it will continuously present a fresh surface across the suction box (which divides the air suspension of dispersed fibers in the duct 34 from the suction box opening) to receive the successive condensation and aggregation of mutually contacting fibers thereon. By regulating the input of fibers and the speed of the belt or screen 37, the thickness of the mass of fibers thus accumulated may be controlled and kept constant.

The rapidly rotated needle brushes 36 sweep or cut off protruding fibers from the free surface of the aggregated fibers, thus reducing the mass to a uniform surface on belt 37 (having a thickness about equal to the length of the pins thereon) without compacting or otherwise altering their random arrangement or their stabilized or fixed relative arrangement with respect to each other.

As the belt 37, with its superposed mass or layer of aggregated fibers thereon, passes out of and beyond the duct 34 the mass may be retained against the attraction of gravity (to which it is then subjected) by the pins 40 and also by passing continuously beneath the opening of suction box 41. As the belt 37 passes beyond the opening of suction box 41 however, it passes above the plain perforated belt 44 which is trained over the opening 51 of suction box 50, located beneath the belt or screen 44 along its inclined portion 48. Consequently the aggregation of fibers on the belt 37 is thereupon transferred as a unit, continuously and completely, off and clear from the pins 40 and down upon the belt 44 which is made to travel at the same rate as the belt 37. The belt 44 may traverse completely below the belt 37 and be made of any suitable material. However, it may be made of perforated or of perforable material such as cheese cloth, so as to be pressed upward and over the projecting pins 40 on the belt 37, thus forming or consolidating the fibrous mass thereon, preliminary to removal from the belt 37.

As thus formed and transferred, the mass or sheet of loose, randomly arranged fibers is stabilized by their mutual contacts, frictions and resistances, only. They may be compacted slightly, if a high degree of suction has been employed in either suction box or if compressed after aggregation, as above described. But this is not necessary and it is a feature of the invention that the apparent density of the fibers as thus aggregated, may be extremely low, and yet the fiber structure is sufficient to stabilize the mass into a temporary or permanent aggregate which may be handled as an integral unitary structure or sheet.

To avoid or prevent subsequent disarrangement of the fibers in handling, it may be desirable uniformly to compact the fibrous mass to a greater apparent density. This may be done by imposing pressure directly upon the fibers, as they stand accumulated upon the horizontal course 48 of the belt 44. For example, this may be done by providing a supporting belt 55, passing beneath the belt 44, which is supported and driven by pulleys 56, 57, and an upper belt 58 passing above the belt 44, supported and driven by pulleys 59, 60. These belts may be impervious and relatively stiff if desired, or flexible, according to the results desired. But they should not be of a rough surface, sufficient to cling to or disrupt the fibrous mass upon contacting or separating therefrom. Additional pressure may be applied while the sheet of fibers is between the two belts, if desired, and various properties may be imposed thereon in the nature of varying pressures to shape or mold the sheet or otherwise shape it or to condition it with liquids, solids, humidity, or other gaseous treatment, or the like, without selective orientation of the fibers.

Since the sheet of random fibers as thus aggregated and stabilized, or rendered permanent per se, though form-retaining, is nevertheless not mechanically strong, it is desirable to provide or develop a bonding medium to impart strength to it. Accordingly, as the sheet comes from the belt 44 it may be treated with a bonding agent. This may be done without a backing, in some cases. But it is convenient to provide a temporary backing sheet 61 and to feed it in on top of the belt 44, as it passes over pulley 45, so that it will receive the fiber mass directly thereon. When this is done, the fiber sheet will come from between the pulleys 57, 60, upon this backing sheet.

Various treatments, with suitable agents and apparatus accordingly, may be employed upon the pre-formed fibrous sheet, depending upon the character of the fibers of which it is composed, and of the aggregation of them effected by the manipulation in the preliminary dispersion, suspension, condensation, forming, and subsequent steps as hereinabove and hereinafter described. This sheet is characterized by comprising or consisting of fibers which are disposed in completely random arrangement in all three dimensions, in direct contact with one another, in such arrangement, so as to prevent freedom of motion and resist or prevent selective relative movement, except by major forces purposefully imposed thereon to effect such movement. It is form-retaining and self-sustaining, even in extremely high states of attenuation or low apparent densities, forming an integrated mass which is subject to handling and other treatments as a unit.

Apparatus illustrative of one type of such after-treatment is shown in Fig. 3, by which the mass or sheet may be impregnated with a liquid, which may be just water or any suitable binding agent in liquid condition. For example, a tank 62 may be provided to contain the impregnating liquid 63, into which is submerged the lower part of a rotatable, perforated drum or screen 64. An endless perforated conveyor belt or screen 65 is also provided, which is trained over pulley 66 thence around the lower portion of the drum 64, over pulley 67, and beneath the press roll 68 mounted thereon, over pulley 69 and down beneath the

vat 62, and beneath return pulleys 70 and 71 which may be positioned in a drip pan 72.

If a backing such as sheet 61 is employed, it will pass with the fiber mass or sheet, off from the belt 44 as the latter passes over pulley 47 and thence onto the conveyor belt 65 as the latter passes into contact with the perforated drum or screen 64. Thence the fiber aggregate is confined between the drum and the conveyor belt, while the liquid is free to wet or impregnate it consistent with the specific characteristics of the fibers, their random aggregation, the liquid employed and the conditions impressed upon them previously and during such treatment.

As the backing sheet and fibers thereon come from between the pulley 67 and the drum 64, they may be subjected to compression by passing between the pulley 67 and compression roll 68 thereon, and thence onto the pulley 69. From here the backing sheet 61 may be separated from the conveyor belt 65 and passed under guide roll 73 to be taken up on roll 74. The fibrous sheet is, in turn, separated from the backing sheet, by a doctor blade if necessary, and allowed to pass freely and continuously upon the conveyor belt 75 which carries it into the drying chamber, as indicated at 76.

After drying, even though water alone has been applied in the impregnating tank, sheets of leather fibers as thus aggregated acquire considerable strength and toughness. This may be considerably increased when the leather scrap from which they have been derived has contained sizing or tanning agents which penetrate the fibers and are rendered adhesive by wetting or saturating with water. But in this form the fibrous sheet is susceptible to substantially any treatment that may be desirable for its future conditioning and use, and it manifests many new properties as a consequence of its three-way completely random, accidental arrangement of the fibers or fibrous components, throughout the mass. When consolidated further by any suitable bonding means or reagents, to a sufficient degree for comparison, it manifests the unique characteristics and properties of real leather which are consequent upon the substantially random arrangement of natural leather fibers, as found in leather made directly from the natural hides of animals. This is a result which, though attempted with many materials and in many ways has not heretofore been accomplished, because the unique relationship of the fibers of natural leather has not been attained.

A further development of apparatus for carrying out the fundamental concept of the invention is illustrated in Fig. 4 in which the fibrous raw material, such as ground scrap leather, may be fed into the hopper 76 of the disintegrator 77, in which they are disintegrated and dispersed by rapidly rotated brushes 78, 79, driven through appropriate belt and pulley connections by the motors 80. The resulting suspension of fibers is removed by the suction fan 81 and delivered through pipe 82 to the furnish box 83 mounted upon frame 84. If the fibers are previously disintegrated and separated sufficiently, they may be fed directly into the furnish box and dispersed therein. The bottom of the furnish box is open, but registers with and is hermetically sealed above the horizontal pass 85 of a continuous perforated conveyor belt or screen 86, which in turn registers with and is hermetically sealed to the top opening 87 of a suction box 88 operated by the suction fan 89, through the pipe 90. The air exhaust from the fan 89 may be led back into the disintegrator chamber through pipe 91 controlled by damper 92.

The continuous conveyor belt or screen 86, is trained over pulleys 93, 94, 95, 96 and 97 so as to pass across the upper opening of the suction box and thence beneath the cylindrical perforated or screen drum 98 which is mounted in the impregnating tank 99, beneath the compression roll 100, into a horizontal pass 101, and thence over pulley 96, which may be the drive pulley for the belt (by any suitable power connection, not shown) and thence back over return pulleys 96 and 97, passing beneath the impregnating vat 99. The pulleys 93 may be provided, as shown, with a takeup mechanism to tension the conveyor belt or to allow for varying compressions or thicknesses of fibers to be deposited upon the belt in any given instance. A deckle strap (not shown) may be mounted longitudinally of the conveyor belt to define the margin of the fibers.

As the dispersed fiber-in-air suspension enters the furnish box, as above described, through pipe 82, it expands throughout the volume of the box and moves downwardly as a whole, under its own impulse and then under the sudden, concomitant impulse of the suction box 88. The haphazardly distributed fibers in the suspension are arrested in this haphazard relationship by the perforated conveyor belt or screen 86, while the suspending medium, being gaseous, passes therethrough without interruption and without orientation of the fibers.

While the fibers are in suspension they are agitated and also impacted by the rapidly rotated rollers 102, and 103, both of which are covered by perpendicularly projecting finely tapered, needle-sharp pins 103, thereon, fairly close to each other, but spaced sufficiently to avoid entangling or entraining the fibrous material.

The action of these rapidly rotated needle points is to further shred or separate the fibers, to a state of individual fiber separation and elongation, to disperse them after such action, and to maintain the dispersed fiber suspension uniform. The rollers on which they are mounted may be rotated in the same or opposed directions, and at the same or different speeds, as desired, by any suitable source of power, not shown. The rollers are also mounted in adjustable bearings, so that the pins in the lower course of their rotation shall pass above the conveyor belt 86 at a height corresponding to the depth of fibers aggregating thereon, at approximately the speed of movement of the fiber suspension, and either with or opposite to the direction of travel of the belt. Both rollers may stand completely above the desired depth of fibers to be formed so as not to affect the aggregation of fibers thereon, or one may stand above the fibers and the other be adjusted to such height that it will sweep off the uppermost fibers and carry them back into suspension. Preferably however, the first roller 102 is adjusted so as to sweep off some of the accumulated fibers from the belt and the second roller 103 is set slightly down so as to sweep off more of the fibers and thus reduce the cumulative thickness of the mass of fibers to a level parallel to the conveyor belt surface. In this action, the hard, sharp points of the needles 103, at the high velocity at which they travel, shear the top or protruding fibers, by impact, and without displacement of them with respect to each other.

A third roller 104, provided with sharp pro-

jecting pins 103, similar to rollers 101 and 102, is mounted above the conveyor belt 86 in the furnish box, and with an adjustable bearing so that its height above the belt may be regulated. But above roller 104 is provided a partition 105, which clears the pins 103 on the roller, but encloses the furnish box otherwise. This roller may be rotated in either direction but preferably opposite to the movement of the conveyor belt 86 and the mass of accumulated fibers thereon. It therefore will still further and more accurately reduce the mass to a given surface and to a prescribed thickness from top to bottom, if this is desired, though it may stand slightly above the mass of fibers so as to leave a rough, somewhat irregular top surface thereon.

On the opposite side of the partition 105 is provided a finishing box 106, into which the conveyor belt 86 and layer of fibers thereon passes, from beneath the pins of roller 104. Herein, another roller 107 having a covering of sharply pointed projecting pins 103 is provided, and mounted above the conveyor belt 86. This roller, also by extremely rapid rotation at the desired height above the conveyor belt, is adapted to cut the fibers and reduce the thickness and the surface of the fiber layer or sheet to accurate dimensions and uniform characteristics of form and consistency.

In some instances it may be desirable to replace the pin roll 104 with a plain, cylindrical pressure roll. This will serve the purpose of consolidating the already aggregated and formed sheet of fibers, before passing under the subsequent pin roller 107, by which it may then be reduced to a more even, smooth surface and more accurate dimensions. Moreover, by such procedure the dry, fibrous sheet may be removed and handled without wetting and hence withdrawn directly in this condition.

The fibers or dust removed from the fiber layer by the pin rollers in the finishing box are withdrawn therefrom by fan 108 and may be discarded or returned to the furnish box 83, through pipe 109, providing a cross-current therein and promoting the random dispersion of all of the fibers.

A vent pipe 110 from furnish box 83 back to the disintegrator (or to the atmosphere) may be provided for the release of temporary pressure in the system. A damper 111 may be provided therein, to shut off such vent pipe if desired, and likewise a damper 112 may be provided for control of the delivery pipe 82 leading to the furnish box 83.

As the conveyor belt 86 comes out from the furnish box and also from the top of the suction box it will carry a layer or sheet, of sharply predetermined dimensions, if desired, but composed of completely randomly dispersed leather fibers, accidentally distributed in respect of directions, sizes, lengths, numbers and amounts, throughout the entire volume thereof both laterally and longitudinally and transversely through the thickness of the layer or sheet. It will be stabilized and relatively permanent in this condition, per se. But for practical purposes of handling, storage, further treatment, etc., on a commercially large scale, where nice precautions are not likely to be observed, it is usually desirable to apply a bonding treatment or medium at this stage to avoid further damage. To this end the conveyor belt is passed, with the fibers thereon beneath a continuous perforated belt or screen 113, which is trained over pulleys 114 and the impregnating roll 98, so that the fibrous sheet is carried between the two perforated belts 86 and 113 and into the liquid or other impregnant or bonding medium 115, in the tank 99. The fiber sheet leaves the belt 113 on the opposite side of the tank and is carried upon the conveyor belt 86 beneath the compression roll 100, if compacting is desired, and thence into the horizontal pass 101 of the belt, on or from which it may be further treated or removed, as desired.

By the procedure of the invention, therefore, a completely random, accidental arrangement of fibers in free, independent dispersion and suspension, in all three dimensions in a gaseous medium, such as the atmosphere, is accomplished. By condensing such dispersion to a point at which the fibers are no longer free and independent in any of the three dimensions or directions, suddenly, the random arrangement and respective relationships of the fibers in all three dimensions are arrested, in status quo, and thus stabilized by their mutual contacts and resistances to further movement in any direction, sufficiently to retain this state permanently, so far as the fibers themselves are concerned. There is no dimension or direction of orientation of fibers in any part of the mass or from one part to another. Hence the completely random fiber arrangement is fixed and the mass as a whole may be further manipulated without loss of such random arrangement, unless it is desired that it shall be modified or disturbed.

In the foregoing description, sufficiently separated or finely divided fibers, and more especially separated fibers of leather have been specifically considered. But it is to be understood that other fibrous materials lend themselves to manipulation and aggregation in accordance with the invention so long as they may be dispersed into a gaseous medium in a three-dimensional uniformity of distribution, and present no impediment to their prompt condensation and aggregation to such a degree as to arrest their free relative movement simultaneously in all three dimensions. Fibers of too high specific densities for dispersion are therefore practically to be excluded, and also fibers which are adherent to each other upon contact, and which accordingly would resist or prevent the original three-dimensional dispersion in a gas as a dispersing medium. But fibers of like or unlike characteristics may be successfully employed. Thus, natural leather fibers, alone, or synthetic fibers, alone, may be satisfactorily employed and manipulated in accordance with the invention. Mixtures of such fibers may also be advantageously employed such as a mixture of natural fibers, such as leather fibers, and of synthetic fibers, such as fine cellulose acetate fibers or filaments, in suitable lengths for free dispersion. With such a fiber mixture and dispersion the procedure may be carried out for their subsequent aggregation and shaping as desired. The resulting shaped product may then be stabilized by subjecting to a bonding medium such as heat (or other medium) whereupon the synthetic fibers become spontaneously superficially tacky and adhere to each other and also to adjacent fibers, upon contact therewith. Such adherent contact, once induced, is substantially permanent. Thus the mass acquires both a unitary shape and a structure which is permanently self-sustaining and form-retaining.

The heat may be imparted to the loose fibrous mass by radiation conduction or convection, with-

out disturbing the fiber arrangement, and to such degree of cohesion or adhesion between the individual fibers as may be required. Of course displacement of the fibers as by compacting, shaping, or otherwise may be effected, but these conditions are not necessary in rendering the loose, contacting random arrangement of the fibers firmly stabilized or permanently associated in such random arrangement, whereby it may be preserved through subsequent manufacturing operations and use. But these properties may be developed readily by calendering or like operations only if desired.

In addition to spontaneous development of the association of the fibers, one to another, and hence without chemical change or adulteration of the fiber aggregation, substantially any reagent medium may be introduced in the form of a gas liquid or solid, which may remain in the fibrous mass or be withdrawn, as desired. Thus solvents of the fibers may be introduced, which dissolve the fibers superficially thus rendering them adhesive or mutually cohesive, and subsequently expelled. Likewise, solvents or other reagents in liquid form also may be left or subsequently withdrawn and washed out of the fibrous mass. Again, solids, in sufficiently finely divided form, in solution or in suspension in liquids or gases, may be introduced, and likewise, left in the mass or substantially withdrawn if desired. The resulting effects may obviously be controlled and determined in terms of the products and properties to be desired.

As above pointed out, it is most readily accomplished to condense or abruptly reduce the volume of the fiber-in-gas suspension sufficiently to effect their aggregation and stabilization by mutual contacts, in one dimension only. But it is possible to effect it in two or three-dimensions simultaneously and preferably to an equal degree in each. Thus the fibers may be dispersed in a gas which is contained in an elastic balloon, which is then subjected from all sides at once to a pressure sufficient to reduce the elastic balloon and its fiber-in-gas dispersion to a shape and volume at which the fibers will come into mutual contact sufficient to arrest their further relative movement. The gas may then be exhausted without disturbance or loss of the random arrangement of the fibers, in all three dimensions. Likewise the fiber dispersion may be subjected to a sudden reduction in volume in two dimensions simultaneously, and to a sufficient degree to bring the free, independent fibers into mutual contact with each other, without reduction in the third dimension.

For example, in this aspect the fiber-in-air dispersion may be formed in a collapsible conduit of wire screening, on the bias, or of stockinet, which is then abruptly collapsed or reduced in cross-section, sufficiently to bring the fibers into mutual contact with one another, thus stabilizing them in their haphazard, three-dimensional relationship. At the same time the gaseous dispersion medium may advantageously be abruptly withdrawn, as by suction through the screen from all sides. And such a reduction in volume, will effectively aggregate the fibers, in their three dimensional random arrangement, into a form-retaining, substantially integrated or unitary fibrous mass, which will retain its size and shape, and also the random arrangement of its fibers, upon releasing or removing the gas from between them, without orientation. Further relationships between the associated contacting fibers may thereafter be developed without disturbing these fundamental characteristics and properties, as desired.

It may also be observed that with leather fibers, if iron surfaces are brought into contact therewith, and especially while wet, the tannic acid or other materials contained therein may be dissolved and react upon the iron, forming products such as iron tannate which discolor the fibers and resulting products. It will therefore be desirable to employ chemically resistant surfaces, such as chromium plated surfaces, stainless steel, or the like in order to avoid such occurrences. With other fibers, whether natural or synthetic, similar considerations will be desirable and provisions made accordingly, if necessary.

It will be understood as comprehended within the foregoing disclosure, and that various modifications and adaptations may be made in the fibrous materials used, in the arrangement of apparatus and in the procedures followed, without departing from the scope of the invention, and that the resulting products may and will be varied and modified accordingly to serve the wide range of uses for which they are applicable, within the purview and definitions of the claims.

I claim:

1. The method of manipulating dry fibers to form a web, comprising the steps of separating and dispersing the individual dry fibers into a gaseous medium, in independent random arrangement with respect to each other in all three dimensions throughout the volume of the gaseous medium to form a floating suspension therein, continuously maintaining the fibers in such floating randomly dispersed suspension at and immediately prior to the instant of web formation and at the point of web formation subjecting said dispersion of fibers to a localized suction thereby instantaneously aggregating the dispersed fibers locally from such dispersed condition into mutual direct contact with each other, in random arrangement, without orientation in any dimension, or dimensions, and collecting such mutually contacting fibers as a matted web, in which the random arrangement of the fibers is maintained and preserved in the web, free from orientation in any dimension, or dimensions, and thereafter bonding the fibers of the web.

2. In an apparatus for manipulating dry fibers to form a matted fibrous web therefrom, the combination of means for separating and dispersing individual dry fibers into a gaseous medium, contained in a chamber, in independent random arrangement with respect to each other in all three dimensions throughout the volume of the gaseous medium, to form a floating suspension therein, means comprising a localized suction means effective upon a portion of the gaseous dispersion of fibers only for aggregating such floating suspension and three dimensional dispersion of fibers in such portion of the dispersion into sudden contact with each other, thereby to bring the dispersed fibers in such portion of the dispersion into immediate mutual contact with each other, thereby to form the contacting fibers as a matted web, in which the random arrangement of the dispersed fibers is maintained in the web formation, and means for maintaining the three dimensional random arrangement and dispersion of the fibers in said floating suspension up to and adjacent the point of said localized suction means and web formation and immediately prior to the instant of web formation, and means for apply-

ing a bonding agent to the thus collected fibers of the web.

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