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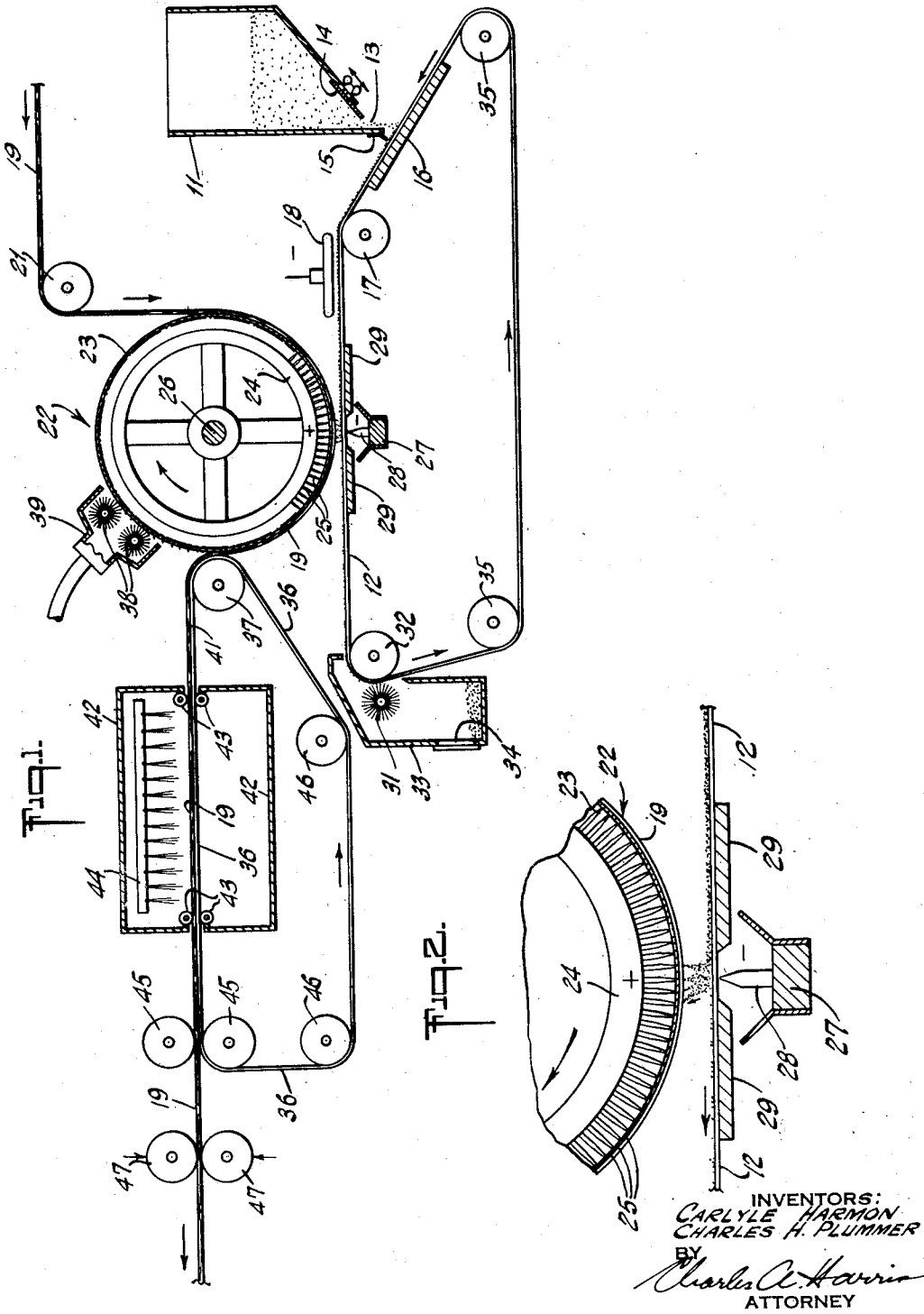
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METHOD OF FORMING NONWOVEN FABRIC

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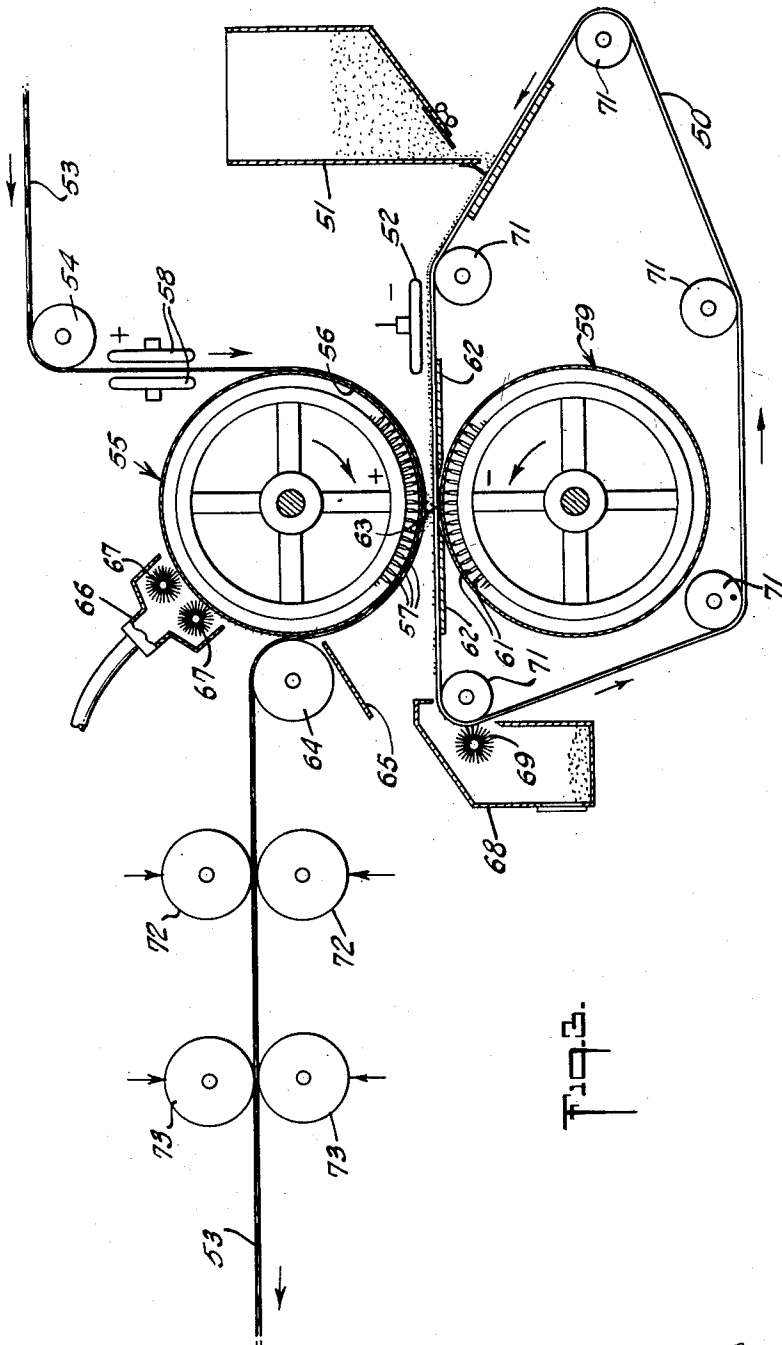


Fig. 3.

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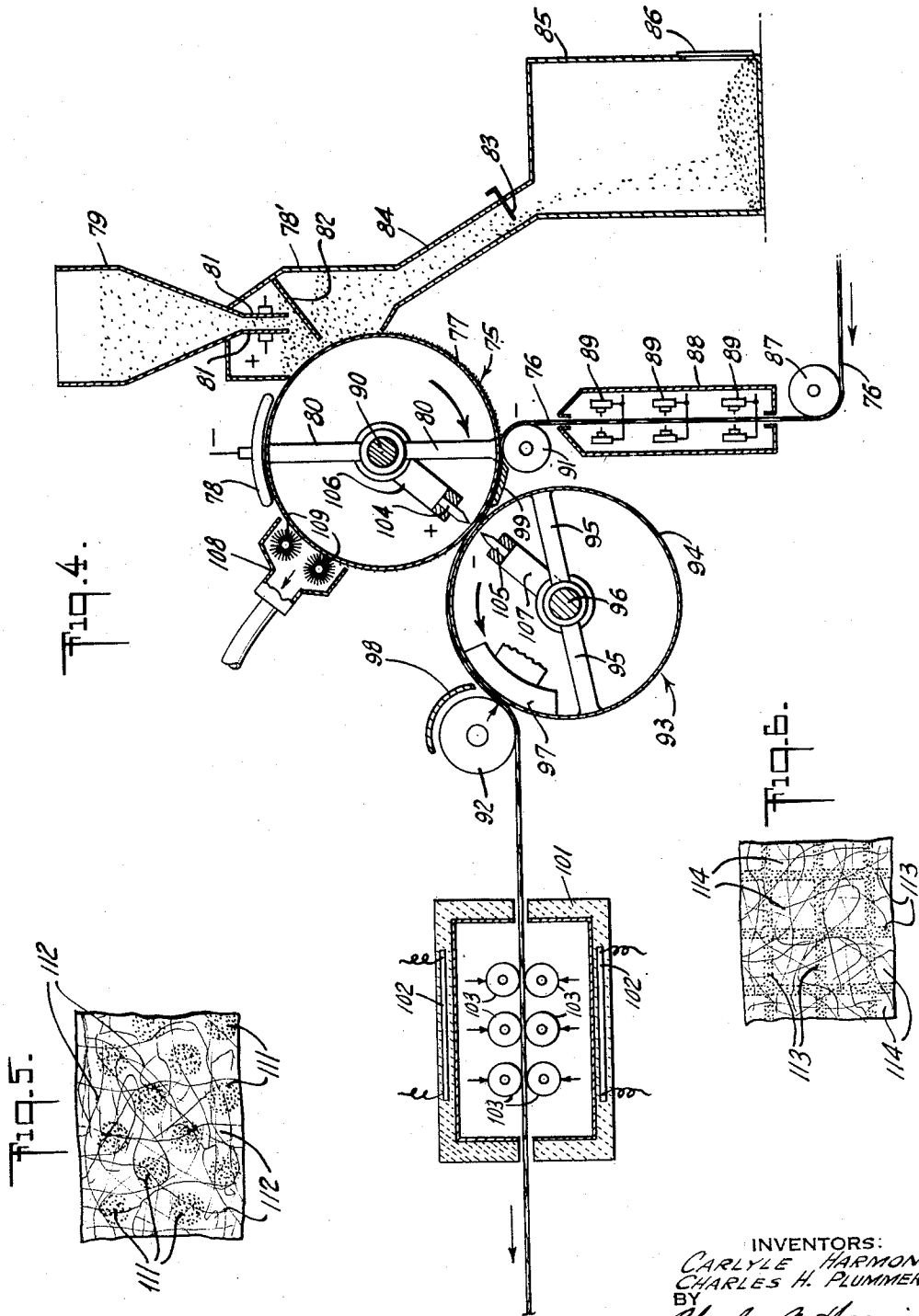
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METHOD OF FORMING NONWOVEN FABRIC

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18 Claims. (Cl. 117—17.5)

This invention relates to methods for producing "nonwoven" fabrics, i. e., fabrics produced directly from fibers without the use of conventional spinning, weaving, or knitting operations. More particularly, it is concerned with methods for producing such fabrics from loosely assembled fibrous webs by bonding the fibers together with an adhesive material deposited in the web according to a predetermined pattern, and nonwoven fabrics formed by these methods.

According to the invention, a bonding material in solid particulate or powder form is distributed throughout a dry web of loosely assembled overlapping intersecting fibers in a pattern covering spaced areas of the web. The binder particles are then softened and pressure is applied to the web to fuse the softened particles together with the fibers and to cause penetration of the softened bonding material into the web. The initial distribution of binder particles in the web is achieved through the use of a controlled arrangement of electric lines of force which operate to transport the particles to the desired areas of the web. The boundaries of these areas may be more or less sharply defined depending upon the electric force applying means employed and the way in which the binder particles are brought into proximity with the web. Webs suitable for use in this process may be formed by a woolen or cotton card or a garnetting machine, in which case the fibers may be oriented predominately in one direction, or by air laying or by forming an iso-web in which the fibers are relatively non-oriented or by laminating any of these in either a lengthwise or crosswise direction.

A thermoplastic binder is preferred since it may be softened and fused in the web by the application of heat and pressure without necessity of moistening the web. It is preferred that the web remain substantially dry to retain a maximum of the fluffiness and soft handle of the original loosely assembled web and to minimize migration or spreading of the binder during softening and fusing. It is preferred that only enough heat be applied to soften the thermoplastic binder particles to the extent necessary to allow them to fuse with the fibers and penetrate through the web during the application of pressure to the web while they are in a softened state. A solvent activated bonding material may be used, in which case, only enough solvent need be added to the web carrying the binder particles to soften these particles to the extent necessary for fusing and penetration, as mentioned above. Sufficient solvent may be added to the web without materially decreasing its fluffiness and loft, by passing it through a "fog" chamber or by spraying a small amount of solvent directly on the web, while supporting it by means, such as a traveling belt.

This process allows the use of "wet-strength" binders or those which are activated by a solvent other than water and/or the application of heat, to form washable nonwoven fabrics possessing excellent wet strength and wet rub resistance. Wet strength and wet rub resistance

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are of particular importance, for example, when fabric made according to this invention is used for covers for sanitary napkins, facing sheets for disposable diapers, towel stock, etc., or, indeed, whenever the fabric must retain its strength or resist abrasion upon exposure to moisture during use.

It is therefore an object of this invention to form a nonwoven fabric from a loosely assembled fibrous web or webs of the type described with most of the fluffiness, soft handle, and drape of the original web or webs, and with high wet strength and wet rub resistance.

It is also an object of this invention to form a nonwoven fabric by applying a bonding material to a web of the type described while the web is maintained dry or nearly dry to retain most of its original fluffiness and soft handle.

Another object of the invention is to apply the bonding material to the web in a nonadhesive or nonsticky state to eliminate many of the web handling problems present when binder is applied to a dry or nearly dry web.

It is a further object of the invention to apply bonding material to a web in a pattern covering spaced areas of the web and, throughout further processing of the web, substantially to restrict the bonding material to the areas in which it was originally applied.

It is a still further object of the invention to simplify manufacture of nonwoven fabrics by applying the bonding material to the web in solid particulate form.

Other and further objects of the invention will be apparent to one skilled in the art from the following description and claims taken together with the drawings wherein:

Fig. 1 is a schematic view of apparatus for practicing a process according to one embodiment of this invention;

Fig. 2 is an enlarged fragmental view partly in section and partly in elevation of a portion of the apparatus shown in Fig. 1;

Fig. 3 is a schematic view, similar to Fig. 1, of apparatus for practicing a process according to a somewhat different embodiment of the invention;

Fig. 4 is a schematic view of apparatus for practicing a process according to a still different embodiment of the invention;

Fig. 5 is a plan view of a fabric typical of that formed by the improved process;

Fig. 6 is a plan view of a different fabric typical of that formed by the improved process.

Referring to Figs. 1 and 2, a supply of a "wet-strength" solvent activated bonding material in solid particle form is fed from a vertical hopper 11 on to the inclined portion of an underlying continuously moving belt 12 through a slot 13 located at the bottom of the hopper and transverse to the direction of travel of the belt. The amount of binder deposited on the belt may be controlled by regulating the width of the aforementioned slot for which purpose an adjustable plate 14 is mounted on the hopper for sliding movement in way of the slot. The continuous belt 12 travels upwardly in an inclined path as it passes underneath the hopper and the thickness of the layer of binder particles deposited on it is determined by the distance between the top side of the belt and the lower edge of a metal or rubber wiper blade 15 depending from the rear wall of the hopper. A suitable table 16 or guide surface is positioned underneath the belt opposite the wiper to assure that the belt will remain properly positioned with respect to the edge of the wiper. Actually an excess of binder may be deposited on the belt from the hopper 11 which the wiper 15 may remove after spreading it to a certain extent, to obtain a uniform distribution of particles on the belt. Also, the table 16 may be adjustable toward and away from the edge of

the wiper to regulate the distance between the belt and the wiper, thereby regulating the thickness of the binder layer. The belt 12 carries the binder particles up away from the hopper over a guide roller 17 and beneath an electrode 18 extending transversely of the belt, which charges the particles. This electrode may comprise means which transfer an electric charge to the particles, or corona discharge needles or wires which spray a charge on them. Any suitable circuit, not shown, may be used to charge the electrode.

A dry base web 19 of loosely assembled fibers, of type described hereinbefore, is led from a suitable source of supply, such as a line of cotton cards, over a guide roller 21 and partially around a distribution drum 22 comprising a thin cylindrical outer wall 23 and an inner shell 24 containing uniformly spaced spikes 25 extending from its surface. The outer wall comprises a dielectric material while the inner shell and the spikes protruding from it are of a conducting material. The ends of the spikes may be in slight spaced relation or in contact with the inner surface of the outer wall as shown in Fig. 2. The spikes 25 act as individual electrodes for defining electric lines of force designed to distribute the binder particles in the web in the pattern desired. Thus, the spikes will at least be co-extensive with the width of the fabric to be formed and will be arranged in the drum to correspond to this pattern.

Spaced from the outer wall of the drum 22 is a comb-like electrode 27 likewise extending the width of the web. This electrode comprises a series of electrode teeth 28 spaced along the electrode in a direction transverse of the web and which resemble the teeth of a comb. The belt 12 carrying the charged layer of binder particles passes between these teeth and the drum with the belt just out of contact with the teeth. A table 29 of dielectric material containing a transverse slot in way of the comb-like electrode may be provided for holding the belt 12 off the teeth 28.

The drum 22 is driven from the shaft 26, such that the spiked electrodes 25 and the outer surface of the drum rotate together with the surface of the drum supporting the web 19. The web moves at the same linear speed as the belt 12 in way of the electrode 27 in spaced relation with the belt carrying the binder particles. The comb-like electrode 27 is connected in circuit with the spiked electrodes 25 in the drum such that a high electrical potential may be applied between them. This potential will cause electric lines of force to pass between the teeth 28 and the spikes 25 to transfer the charged particles from the belt to the web. In order for this to occur, the comb must be charged with the same sign as the particles and the spikes with the opposite sign. Thus, if the binder particles are negatively charged, the teeth 28 negatively charged, and the spiked electrodes 25 positively charged, the negatively charged particles will be repelled by the negatively charged electrodes and attracted by the positively charged electrodes to move from the belt to the web. The spacing between proximate portions of the drum and the belt must be controlled to assure that they are not so close that the particles on the belt will be materially disturbed in position or picked up by the web before they fall under the influence of the aforementioned electric lines of force, and to assure that they are not so far apart as to increase the gap between the electrodes 25 and 27 beyond practical limits. Guide rollers or a slide, not shown, in contact with the edges of the belt may be provided to hold it against movement by electric attraction towards the web.

As mentioned hereinbefore, the spiked electrodes 25 are arranged in the drum to correspond to the pattern in which it is desired to deposit the binder particles in the web. The electric lines of force entering each of the spikes will pass through a corresponding area of the web. While the major lines of force tend to concentrate

between the tips of these electrodes, they will fan out as they pass from one to the other, such that the spikes must be located with this fanning out in mind to assure that the resulting binder areas form the desired pattern in the web.

As the binder particles are deposited in selected areas of the web 19, they are removed from related, perhaps less definitely defined, areas of the belt 12, leaving a residue of binder particles on the belt. This residue of particles may be removed from the belt by a cleaning brush 31 which rotates against the belt as the belt passes over a guide roller 32. The brush and adjacent portions of the belt are preferably enclosed in a hood 33 for collecting the particles as they are removed by the brush 31. The particles may be allowed to settle and then removed from the hood through an access opening 34 provided for this purpose or they may be recirculated by means, not shown, such as ducts and a circulating fan, back into the hopper 11 for reuse. The belt with particles removed returns to the hopper around guide rollers 35 which space the return flight of the belt from that bearing the particles.

As the drum 22 rotates, the web 19, which now contains the binder particles arranged according to the desired pattern, leaves the zone of transfer between the electrodes 25 and 27 and moves in contact with the drum to a location adjacent a continuous conveyor belt 36 which, at such location, also moves in the same direction and at the same linear speed as the surface of the drum. The web is transferred from the drum to the conveyor belt 36 and moves with the belt around a roller 37 which holds the belt in close proximity with the drum 22. The spiked electrodes 25 remain charged during the time the web moves in contact with the drum from the transfer zone to the conveyor belt 36. Since the web comprises loosely assembled fibers, this charge is believed necessary to assist in holding the dry binder particles in position in the web and prevent them from falling back upon the belt 12 or floating away from the web in air currents created by the moving mechanisms. A certain small percentage of the binder particles will be attracted through the web and will remain on the drum 22 after the web is transferred from the drum on to the conveyor belt 36. Rotating brushes 38 mounted in a vacuum duct 39 may be employed for removing these particles and any other foreign material of this type from the drum prior to its again contacting the web 19. A suitable exhaust fan, not shown, may be connected to this duct for applying a vacuum thereto.

After it leaves the drum, the web containing the binder is supported by a horizontally moving flight 41 of the aforementioned conveyor belt 36. Located in the path of the horizontally moving belt is a spray chamber 42 for uniformly distributing a solvent for softening the binder particles in the web. This chamber may be closed at each end with entrance and exit slots each presenting opposed guide rollers 43 for the passage of the conveyor belt carrying the web. The solvent may be injected into a closed chamber of this type through a header 44 for creating a fine spray such that the solvent may be present throughout the chamber as a "fog" or cloud-like dispersion of small particles which will only wet the web to the extent necessary to soften the particles, while not materially detracting from its fluffiness and soft handle. It is also important that the solvent enter the web in a gentle manner so as not to dislocate or wash out the binder particles. The belt 36 with the web 19 thereon containing the softened binder particles leaves the spray chamber and enters the nip between a pair of pressure rollers 45 which are adjusted to exert sufficient pressure on the binder particles to fix them in position in the web. Thereafter the web and the belt separate as they leave the nip of the rollers 45, the belt traveling around spaced rollers 46 to return to the drum 22, and the web passing through the nip of a second set of pressure rollers 47. The second set of

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pressure rollers is adjusted to exert greater pressure on the web and the binder particles than did the first set of rollers 45; to fuse the still softened particles with contiguous fibers in the web and assure penetration of the binder through the web. It is preferred that pressure be applied to the web in two steps, as described above, to prevent the web from being fused to the belt 36 before the belt and the web are separated. The web, leaving the second set of pressure rollers 47, may pass over conventional textile drying cans, not shown, to remove any excess solvent, after which the finished fabric may be rolled up for storage or use, as desired.

Referring to Fig. 3, there is shown a similar, but slightly different, embodiment of apparatus for performing the process of the invention. This embodiment is particularly suitable for use with a thermoplastic bonding material. Dry thermoplastic binder particles, preferably of a wet strength type, are deposited on a continuously moving belt 50 from a hopper 51 and charged by an electrode 52 provided for this purpose, as in the embodiment previously described. Also, a loosely assembled fibrous web 53 is drawn from a source of supply, not shown, around a guide roller 54 and then partially around a distribution drum 55 comprising an outer dielectric shell 56 and inner spiked electrodes 57, as shown in Fig. 1. However, the web is charged oppositely to the binder particles before it comes into contact with the drum by electrodes 58 spaced for this purpose on opposite sides of the web. The web may pass between these electrodes, both of which carry the same charge, just after it leaves the guide roller 54.

In this embodiment the comb-like electrode 27 of Figs. 1 and 2 is replaced by a drum 59, similar in all respects to the overlying distribution drum 55, i. e., having spiked electrodes 61 arranged in a pattern corresponding to the pattern of the electrodes 57 in the distribution drum. The continuous belt 50 carrying the binder particles passes between the two drums, in spaced relation with the distribution drum 55. A table 62 defining a transfer gap 63 is provided between the second drum and the belt which may be similar to the corresponding table 29 of Figs. 1 and 2, and may comprise a dielectric plate or plates defining a transverse gap 63 for the passage of electric lines of force between the two drums. The dielectric portions of the table will prevent interaction between the spiked electrodes 57 and 61 of the first and second drums before they are properly located with respect to one another to define the desired lines of force between them. The electrodes of the two drums are electrically connected in a manner to apply a relatively high potential between them, such that the first drum 55 carries the same charge as the web 53 and the second drum 59 carries the same charge as the binder particles. Thus, if the binder particles are negatively charged, they will be repelled by the negatively charged spiked electrodes 61 of the lower drum as the particles pass over the transverse slot 63 in the dielectric table and will be attracted by the positively charged spiked electrodes 57 of the upper drum. It is important that the amount of charge on the web 53 be controlled to prevent it from interfering with the lines of force entering the spiked electrodes in the upper drum and thereby interfering with the deposition of binder particles in the pattern desired. The charge on the web is for the purpose of holding the binder particles in position once they are deposited therein, and will tend to prevent these particles from being pulled through the web to the outer surface of the upper drum 55 such that they will be lost to the web when it leaves the drum.

It is preferred that the thermoplastic binder particles be fixed in position in the web before the web is separated from the distribution drum 55. This may be accomplished by providing a heated roller 64 adjacent to, or in contact with, the drum 55, which rotates with the drum in such a way that the surfaces of the drum and the roller move at the same linear speed. The web may

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be squeezed slightly between the heated roller 64 and the drum and then pulled off the drum as it passes around the roller in contact with its heated surface. The roller 64 may be heated by any suitable means, such as electrical heating coils, not shown, which may be regulated to control the drum temperature such that it will only be sufficient to soften the binder particles slightly as the web passes over the roller. Higher temperatures may create difficulties in separating the web from the drum and cause some of the binder particles to fuse to the drum surface. A shield 65 may be provided below the roller 64 as a protection for any binder particles which may be carried by the continuous belt 50 below it. A vacuum duct 66 containing rotating brushes 67 may be supplied for cleaning excess particles from the surface of the distribution drum 55 after it leaves the web and a hood 68 enclosing a brush 69 for removing excess particles from the belt 50 may also be provided, as described in connection with Fig. 1. Spaced rollers 71 support and drive the return flight of the belt in manner similar to that described in connection with the embodiment of Fig. 1.

After leaving the heated roller 64, the fixed binder particles may then be fused in the web by passing the web 53 between sets of heated pressure rollers 72 and 73, such as hot calenders. These may be heated by steam or by electrical heating coils or by other means which may be regulated to control the temperature of their surfaces, and it is preferred that the rolls be adjustably mounted to regulate the pressure between them. The heating and pressure steps for fusing the particles in the web could be separated, in which case the web might be passed through an oven and then between pressure rollers. This may be preferred for certain types of binders which become thermoplastic only at very high temperatures. Sufficient time should be allowed after fusing for cooling or hardening of the binder before the resulting fabric is used.

In the embodiments of Figs. 1 and 2 and Fig. 3, charged binder particles are transferred directly from a continuous body of particles to a base web of loosely assembled fibers by electric lines of force entering a series of electrodes arranged in a pattern. The lines of force deposit the particles in the web in a pattern corresponding to the arrangement of these electrodes. Careful installation, adjustment and spacing between the moving drum and belt will give a relatively sharp pattern of deposition without undesirable fuzziness when transferring selected particles from a continuous layer of moving particles by electric lines of force, using such systems. However, should greater accuracy of transfer be desired, apparatus of the type illustrated in Fig. 4 may be used. As shown, charged binder particles are first deposited in a pattern on a drum 75 having surface areas defining this pattern, and then transferred from this drum to a base web 76 by electric lines of force. The pattern for depositing the particles in the web is the same as the pattern in which they are carried on the drum, so that there is no problem of selection or rearrangement in transferring the particles from the drum to the web. The pattern drum 75 includes an outer shell 77 comprising a conducting base containing spaced areas of a dielectric material arranged in the desired pattern on its outer surface. The dielectric material may comprise plastic discs or strips, which are inserted in the conducting base, or a suitable insulating lacquer or paint may be applied to the conducting base in the desired pattern. The conducting portion of the shell is grounded, such that if a given charge is impressed on the shell surface, it will remain on the surface of the dielectric pattern defining areas and will disappear from the surrounding conducting areas to ground. Thus, the pattern drum may be mounted to rotate beneath a fixed electrode 78 which transfers a portion of its charge to the drum or sprays a charge on the drum's surface,

The electrode 78 is preferably of the type which is capable of spraying a corona discharge. As mentioned above, as the shell 77 passes beneath this electrode, only the pattern defined by the dielectric portions of its surface will remain charged. The shell 77 is fixed to end supports 80, which in turn are attached to the rotating shaft 90 which drives the drum.

The charged drum is then rotated through an application chamber 78', through which passes a shower of dry charged thermoplastic binder particles, preferably of wet strength type, and supplied from an overlying hopper 79 mounted in the top of the application chamber. The particles fall from the hopper into the application chamber through a passage way or aperture which is defined in part by a pair of electrodes 81, carrying both the same charge which is opposite to that of the electrode 78. The passage is designed to assure that most of the binder particles passing through it will pick up a charge corresponding to that on the electrodes 81. A baffle 82 provided at the end of this aperture deflects the particles passing therethrough on to the rotating drum 75. However, since the binder particles are relatively fine and light and since most of them carry an electric charge, a large percentage of them may float about in the chamber in the form of a "cloud." The charged areas of the drum, coming into close proximity with the oppositely charged binder particles, attract such particles either from the falling spray or from the cloud, and are fairly well covered by the time they leave the application chamber. The concentration of binder particles in the application chamber may be controlled by regulating a damper 83 adjustably arranged in an outlet duct 84 which empties into a collection chamber 85 having a door 86 for removal of excess binder. The binder particles may be recirculated for reuse from the collection chamber to the hopper by means, not shown, such as ducts and a circulating fan. The binder particles may be carried on other larger particles selected from a different material higher or lower in the triboelectric series such that the binder particles will be charged oppositely to the electrode 78 by virtue of their triboelectric relationship with these particles. In such a system the electrodes 81 are unnecessary and the larger particles carrying the binder particles may be allowed to drop from the hopper 79 such that they will be deflected by the baffle 82 to cascade over the surface of the rotating drum 75 within the application chamber 78'. The dielectric areas of the drum carry a stronger charge than the moving carrier particles in order to attract the binder particles therefrom and hold them in position on the drum, while the carrier particles are of such sizes and weights that they will fall from the drum through the duct 84 into the collection chamber 85.

A loosely assembled fibrous base web 76, of the type described hereinbefore, is led into contact with the drum 75 carrying the charged particles. Preferably, this web is charged oppositely to the binder particles carried on the drum before it comes into contact therewith. This may be accomplished by passing the web around a guide roller 87 and then through a charging chamber 88 between a number of corona spray discharge electrodes 89. The chamber helps to concentrate the charge on the web and prevent fouling of the electrodes by binder material which may escape from the application chamber 78' or fall from the rotating pattern drum. The charged web, moving at the same linear speed as the drum 75, leaves the chamber 88 and passes over a guide roller 91 into contact with the binder particles carried on the pattern drum. The oppositely charged web will be attracted to the binder particles and held by them against the drum. It is preferred that the charge on the web 76 be appreciably greater than the charge on the dielectric portions of the drum 75, such that the binder particles will be attracted from the surface of the drum to the web by

the stronger lines of force between the particles and the web. When the web is so charged, it is preferred that it be allowed to remain in contact with the pattern drum over a portion of the drum's travel to gain full advantage of the charge it carries and allow a fairly complete transfer of the binder particles from the drum to the web. Thereupon the web may be separated from the pattern drum 75 and passed into contact with a heated roller 92 spaced from said drum for fixing the particles in place in the web. The roller 92 need only be heated to the extent necessary to soften the binder particles for fixing them in the web and is designed to cooperate with adjacent means to exert sufficient pressure on the web to press the softened particles together with the fibers in the web to hold the particles in position. Means, preferably in the form of a roller or drum 93, must be provided on the opposite side of the web for cooperating with the heated roller for this purpose. It is preferred that a surface be provided for supporting the web carrying the binder particles between its point of departure from the pattern drum 75 and the point where it comes into contact with the heated roller 92. While it is preferred that the web be pre-charged such that the charge remaining on the web will be sufficient to hold the binder particles in position, this surface will tend to steady the web and thereby help to prevent them from becoming dislocated. In the event that the web is not pre-charged, this supporting surface will tend to prevent particles from falling from the web before they reach the heated roller 92. As shown in Fig. 4, such a surface may be presented by the aforementioned drum 93. The drum 93 is preferably similar to the pattern drum 75 and mounted such that its surface is slightly spaced from that of the drum 75 and moves at the same linear speed therewith. Thus, the web may be drawn away from the pattern drum 75 in contact with the second drum 93 until it reaches the heated roller 92. The heated roller may be adjusted to press the web against the surface of the drum 93 to fix the particles in the web. The second drum 93 may comprise a dielectric outer shell 94 fixed to end supports 95 attached to the rotating shaft 96 which drives the drum. The drum passes over a fixed segmental inner member 97 which supports the relatively thin shell 94 against the pressure exerted by the heated roller 92. The roller 92 may be heated by any suitable means such as steam coils or internal electrical heaters, etc., which may be regulated to maintain the roller at the desired temperature. A shield 98 may be provided between the roller 92 and the pattern drum 75 to prevent heating this drum and fusing binder particles on its surface. Also, a guide surface or shoe 99 may be provided between the roller 91 and the second drum 93 to provide additional support for the web and prevent binder particles from dropping therefrom.

After leaving the heated roller 92, the web with the binder fixed therein may pass through an oven 101 which heats the binder particles to soften them further. Heat may be supplied to the oven by means such as electric heating coils 102, which may be regulated to maintain the oven at the desired temperature. Pressure rollers 103 for fusing the heated binder particles with the fibers in the web to the extent necessary for penetration and strength may be included within the oven 101, as shown, or outside the oven adjacent thereto. The web containing the fused binder particles may then be allowed to cool to provide a nonwoven fabric held together with appropriately spaced areas of binder.

In the event that the web 76 is not pre-charged, or is not charged to the extent necessary to cause a fairly complete transfer of the charged binder particles from the pattern drum 75 to the web, a pair of oppositely charged electrodes 104 and 105 may be provided for creating electric lines of force for this purpose. One electrode 104 may be mounted in a fixed position on a fixed frame 106 inside the rotating pattern drum and the other electrode 105 may be mounted in a corresponding fixed position,

opposite the first electrode, on a correspondingly fixed frame 107 inside the second rotating drum. These electrodes may be of the comb-type, as described in connection with Figs. 1 and 2, and are connected in circuit such that a high electrical potential may be applied across them. This potential will cause electric lines of force to pass from the teeth of one electrode through the dielectric surface of the two drums to the teeth of the other electrode. If the web is pre-charged in the manner previously described, the lines of force generated by these electrodes may be controlled to provide a booster effect which will assist in transferring the particles from the pattern areas on the drum to the web. In order for this to occur, the upper electrode 104 within the pattern drum must be charged with the same sign as the binder particles, while the lower electrode 105 must be charged with the same sign as the web and the dielectric pattern defining areas of the shell 77. If the web is not pre-charged, the lines of force between the upper and lower electrodes must be great enough to cause a complete transfer of binder particles from the pattern drum to the web. As has been suggested hereinbefore, the importance of a supporting surface for the web from the time it takes possession of the binder particles until these particles are fixed in position by the heated roller 92, increases as the charge in the web decreases. In other words, while it is preferred to provide this support whether or not the web is charged, if the web is not pre-charged, such support is considered necessary.

Even with a pre-charged web and booster electrodes, it is probable that some binder particles will not be transferred to the web and will remain on the surface of the pattern drum 75. A vacuum duct 108 containing rotatable cleaning brushes 109 is provided for removing these excess particles. A suitable exhaust fan, not shown, may be connected to this duct for applying a vacuum thereto.

As described hereinbefore, the binder particles are deposited in the fibrous base web in spaced areas of said web. These spaced areas may comprise disconnected islands 111, containing binder particles, surrounded by a sea 112 of fibers relatively free of binder, as shown in Fig. 5, or they may be in the form of spaced areas 113, containing binder, connected with one another to form a reticular structure enclosing areas 114 of the web relatively free of binder, as shown in Fig. 6. By spacing the areas of binder deposition with relation to the average length of the fibers, strength may be obtained with economy, and the softness, hand, and drape of the original web can be preserved to a great extent.

It will be seen that we have provided a process for forming a nonwoven fabric from a loosely assembled fibrous web, wherein the resulting fabric retains most of the fluffiness, soft handle, and drape of the original web. Since this process is particularly suitable for the application of wet strength binders, this fabric may be designed to have high wet strength and wet rub resistance. The bonding material may be applied directly to dry webs of loosely assembled fibers without creating web handling problems and once it is applied to the web it will not migrate to any extent away from the pattern areas to detract from the textile qualities of the resulting fabric. Solid binder particles may be applied to spaced areas of the web by means of electric lines of force, and then fused in the web to create a nonwoven fabric, by a simplified process which minimizes operating problems while providing a superior textile-like product.

The invention claimed is:

1. The method of forming a nonwoven fabric from a loosely assembled fibrous web, which comprises distributing dry charged particles of an adhesive material throughout the web in a predetermined pattern by means of electric lines of force, softening the particles in the web to an adhesive state, and hardening said particles in adhesive contact with fibers in the web to bond them together and form a fabric.

2. The method of forming a nonwoven fabric according to claim 1, wherein the web and the particles contained therein are supported from the time the particles enter the web until they become softened and fixed in position in the web.

3. The method of forming a nonwoven fabric according to claim 1, wherein the adhesive particles are thermoplastic and the particles are softened to an adhesive state by the application of heat.

4. The method of forming a nonwoven fabric according to claim 1, wherein said web is passed between oppositely charged electrodes at least one of which is designed to cause said electric lines of force to flow between the electrodes in the pattern desired, and wherein the particles carrying an opposite charge to the electrode adjacent said web are also passed between said electrodes in spaced relation with said web, whereby the particles will follow said lines of force toward the oppositely charged electrode to distribute themselves in the web in a predetermined pattern.

5. The method of forming a nonwoven fabric according to claim 1, wherein pressure is applied to the web containing the softened particles to bring the particles into further contact with the fibers in the web.

6. The method of forming a nonwoven fabric according to claim 5, wherein said particles are electrically charged and said streams are defined by electric lines of force.

7. The method of forming a nonwoven fabric from a loosely assembled fibrous web, which comprises charging the web, distributing dry charged particles of an adhesive material throughout the web in a predetermined pattern by means of electric lines of force, softening the particles in the web to an adhesive state, and increasing contact between the softened particles and the fibers in the web by the application of pressure thereto.

8. The method of forming a nonwoven fabric from a loosely assembled fibrous web, which comprises distributing dry charged particles of an adhesive material in a predetermined pattern on a supporting surface, charging said web oppositely to said particles, advancing the web into close proximity with the particles on said supporting surface whereby the web will attract the particles from said surface, removing said web carrying said particles from the area of close proximity with said supporting surface, softening the particles in the web to an adhesive state, and increasing contact between the softened particles and the fibers in the web by the application of pressure thereto.

9. The method of forming a nonwoven fabric according to claim 8, which further comprises supporting said web carrying said particles from the time it leaves said supporting surface until the particles become sufficiently soft to be fixed in position in the web.

10. The method of forming a nonwoven fabric according to claim 8, wherein said charged particles are held on said first mentioned supporting surface by a pattern of opposite charges carried by said surface.

11. The method of forming a nonwoven fabric according to claim 10, wherein the charge on said web as it comes into contact with said particles is substantially greater than the charge on said first mentioned supporting surface.

12. The method of forming a nonwoven fabric from a loosely assembled fibrous web, which comprises distributing dry charged particles of a thermoplastic adhesive in a predetermined pattern on a supporting surface, charging said web oppositely to said particles, advancing the charged web into close proximity with the particles on the supporting surface whereby the web will attract the particles from said surface, removing the web carrying the particles from the area of close proximity with said supporting surface, applying heat to the web to soften said particles to an adhesive state, and allowing said

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particles to cool in adhesive contact with fibers in the web to bond them together and form a fabric.

13. The method of forming a nonwoven fabric according to claim 12, wherein the charged web is continuously supported from the time the web contacts said particles until sufficient heat is applied to the web carrying the particles to fix the particles in position in the web.

14. The method of forming a nonwoven fabric according to claim 13, wherein only as much heat is applied to the web carrying said particles while the web is continuously supported as is necessary to fix the particles in position in the web, which further comprises applying additional heat and pressure to the relatively unsupported web to soften the particles further and bring them into further contact with the fibers in the web.

15. The method of forming a nonwoven fabric from a loosely assembled fibrous web, which comprises distributing dry charged particles of an adhesive material in a predetermined pattern on a supporting surface, advancing said web into close proximity with the particles carried by said first mentioned supporting surface, transferring said particles from said first mentioned supporting surface into said web by means of electric lines of force while supporting said web on a second supporting surface, removing said web carrying said particles on said second mentioned supporting surface away from the area of close proximity with said first mentioned supporting surface, softening said particles and fixing them in position in the web while the web is still carried by said second mentioned supporting surface, and softening the particles further and applying pressure to the web to bring them into further contact with the fibers in said web.

16. The method of forming a nonwoven fabric ac-

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ording to claim 15, wherein said web passes between spaced oppositely charged electrodes in the area of close proximity between said first and second mentioned supporting surfaces and said electrodes generate said electric lines of force in this area for transferring said particles from said first mentioned supporting surface to said web.

17. The method of forming a nonwoven fabric from a loosely assembled fibrous web which comprises distributing dry particles of an adhesive material in a pre-determined pattern in the web by means of streams of said particles striking the web in said pattern, softening the particles in the web to an adhesive state and hardening them in contact with the fibers to form bonds between fibers in the web areas covered by said pattern.

18. The method of forming a nonwoven fabric from a loosely assembled fibrous web, which comprises arranging dry particles of adhesive material in a predetermined pattern in spaced areas of a carrier member, each of said areas containing a multiplicity of said particles, passing said web adjacent the spaced areas of said member, transferring said particles to corresponding areas of said web, softening the particles in the web to an adhesive state, and hardening them in contact with the fibers to form bonds between fibers in the aforesaid areas of said web.

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