June 23, 1964 K. A. GELPKE 3,137,893

APPARATUS AND PROCESS FOR MAKING APERTURED NON-WOVEN FABRICS

Filed Dec. 6, 1954 4 Sheets-Sheet 1

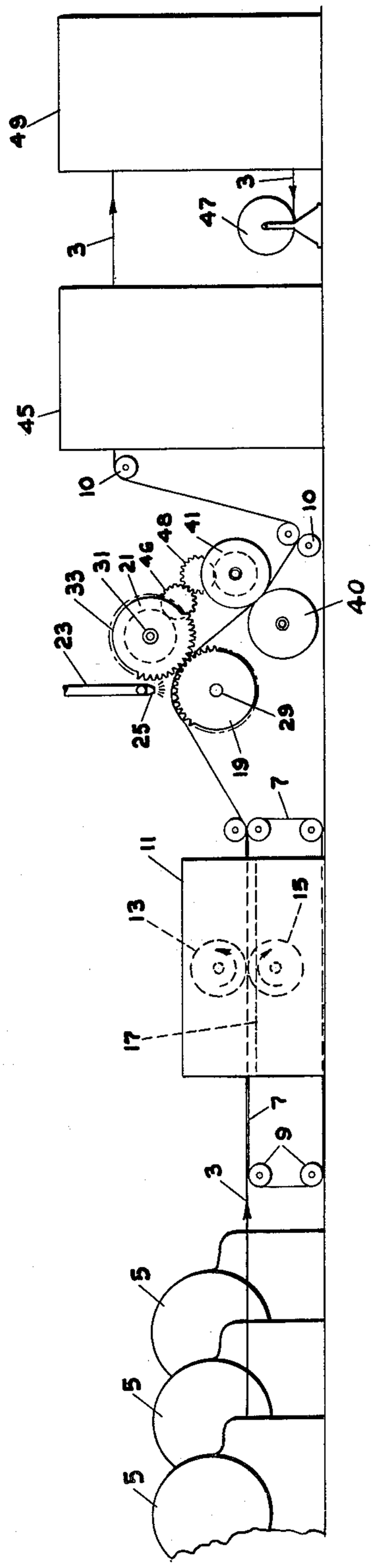

FIG. 1

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FIG. 2

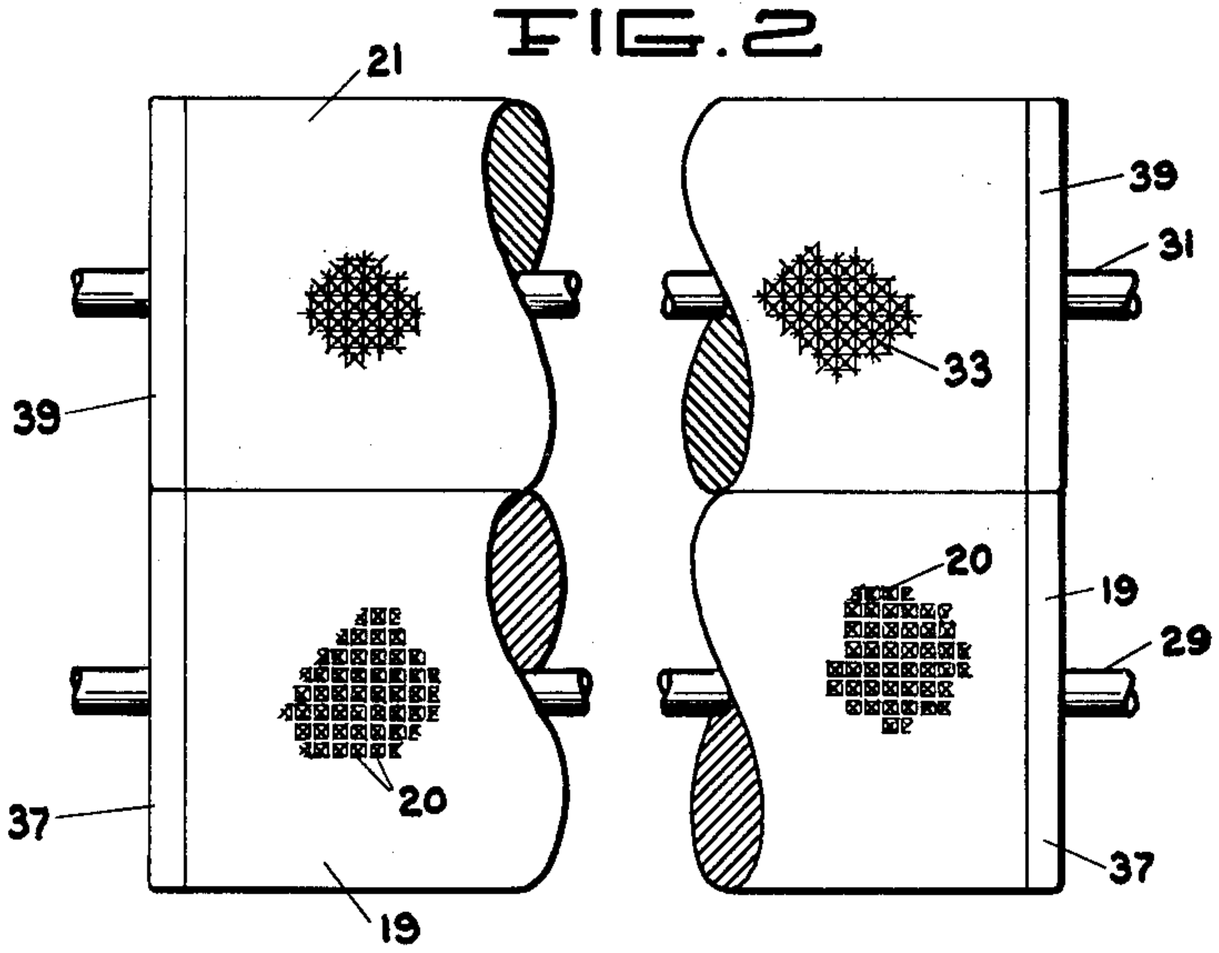
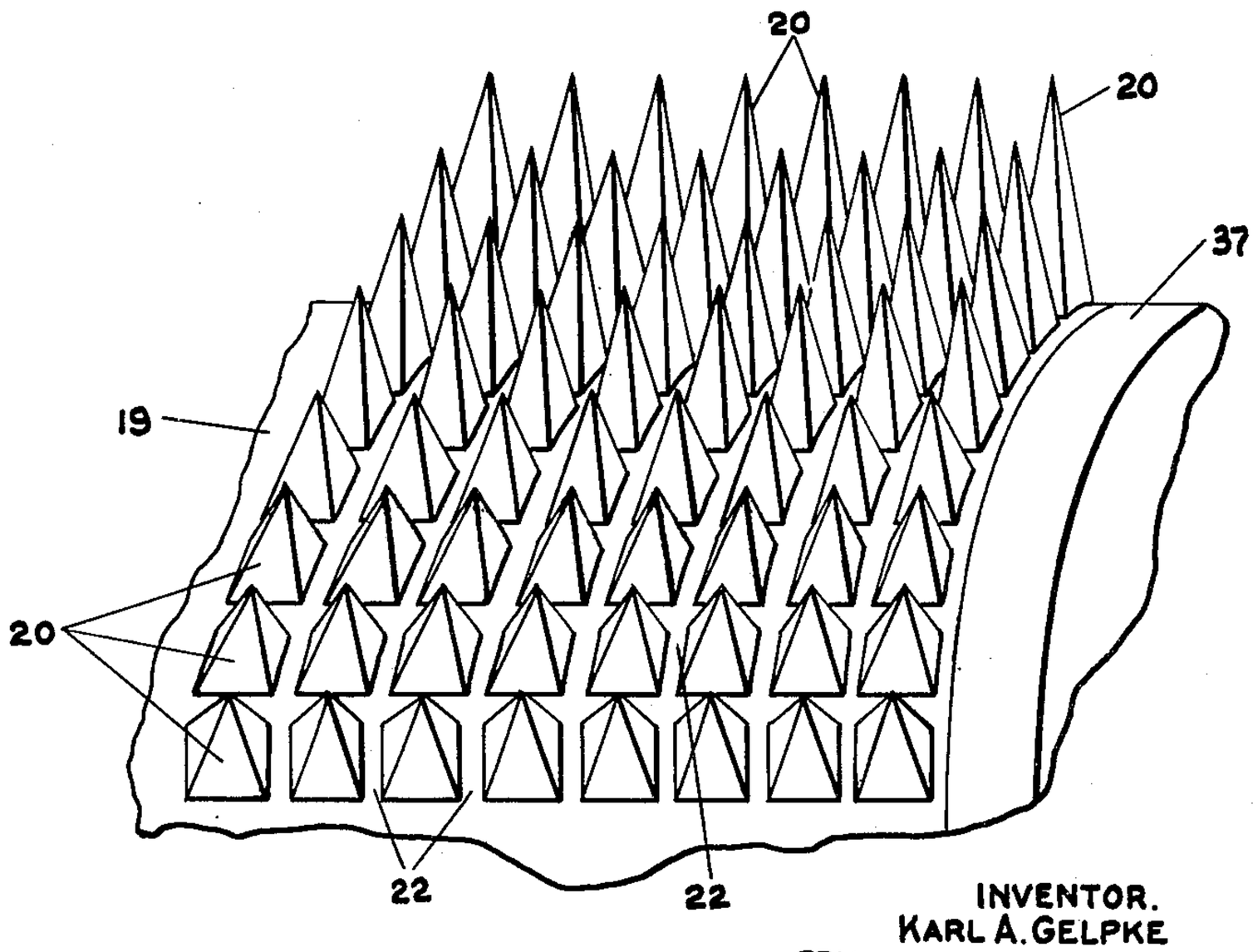


FIG. 4



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APPARATUS AND PROCESS FOR MAKING APERTURED NON-WOVEN FABRICS

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FIG. 5

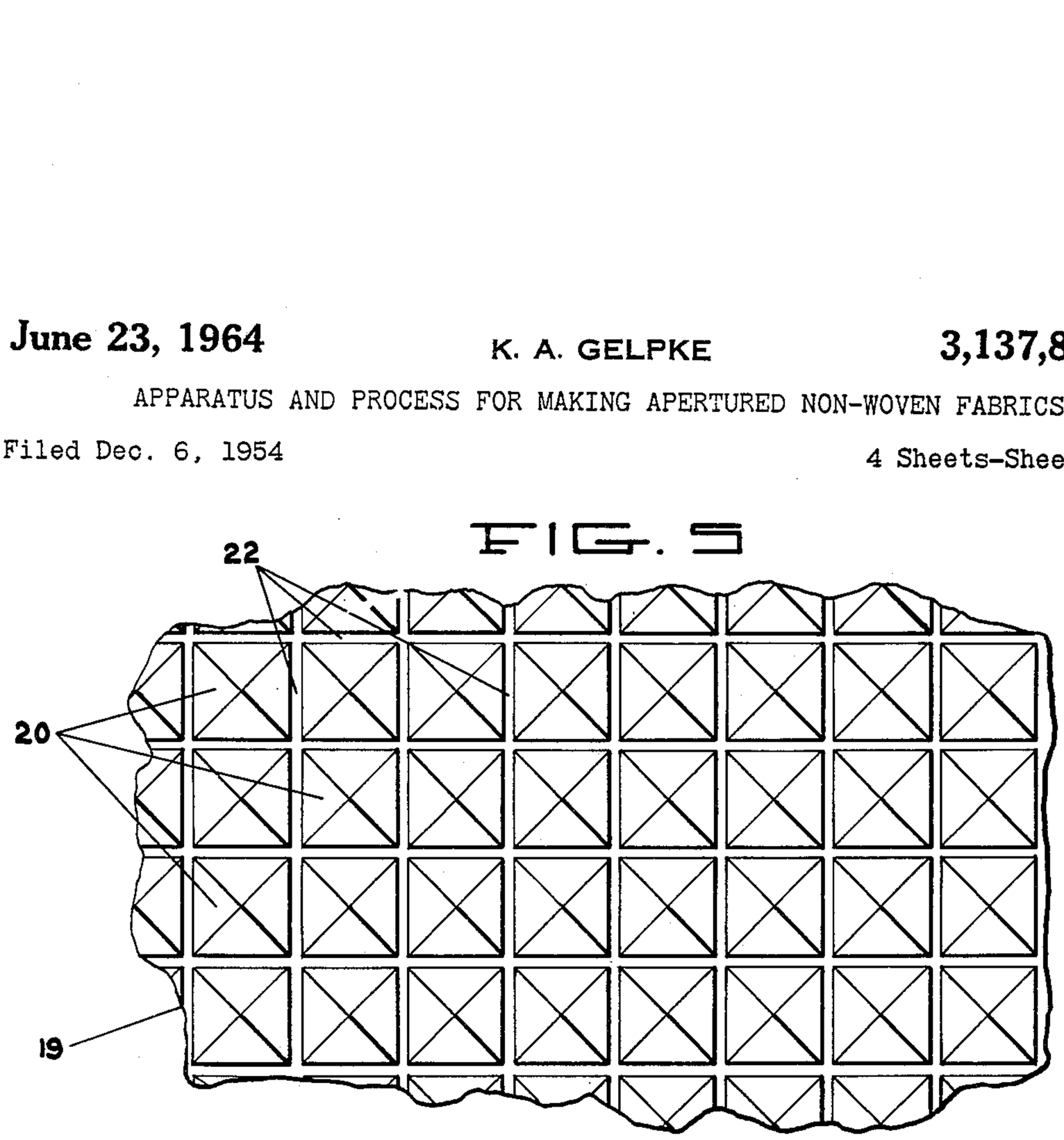


FIG. 6

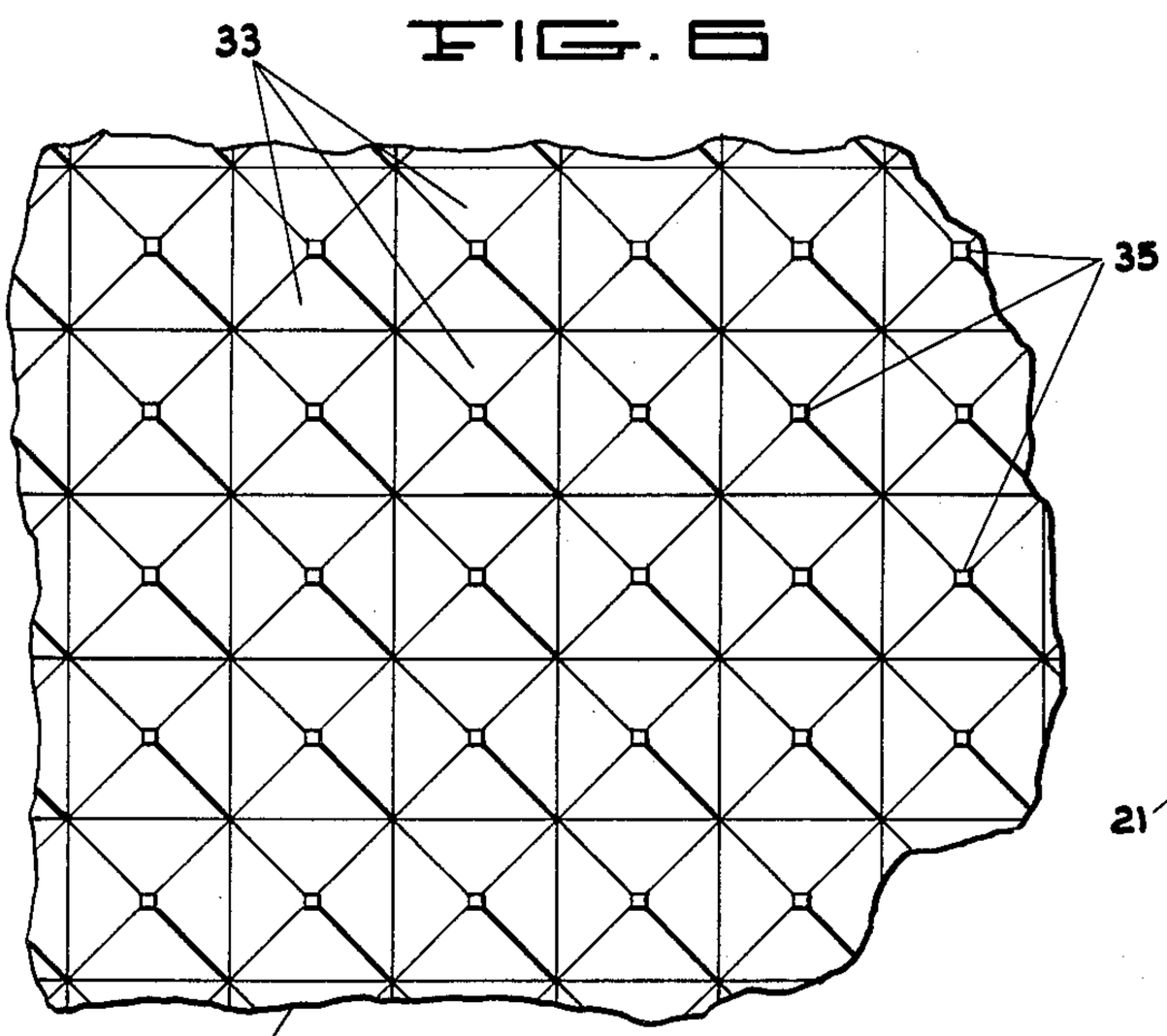


FIG. 11.

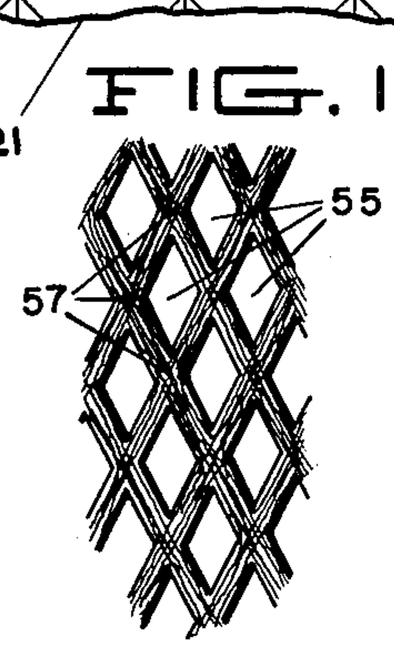
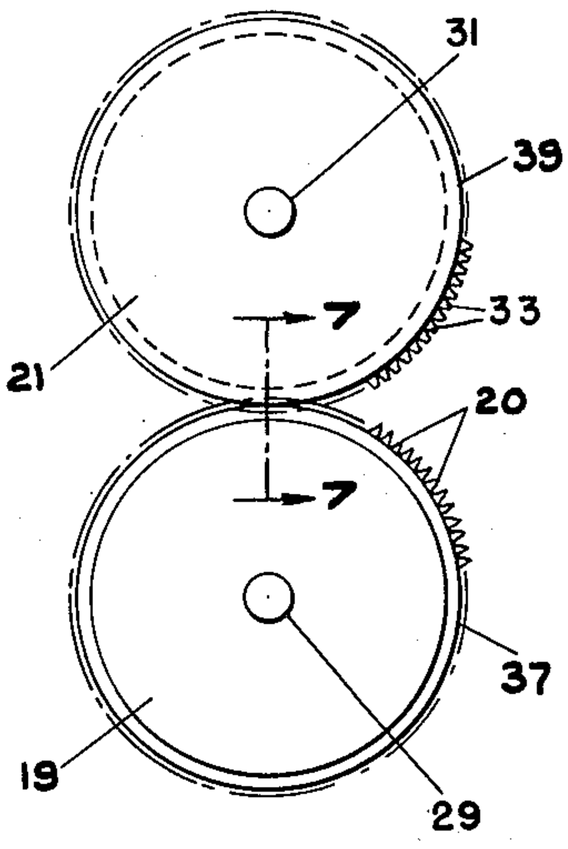


FIG. 3



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APPARATUS AND PROCESS FOR MAKING APERTURED NON-WOVEN FABRICS

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FIG. 7

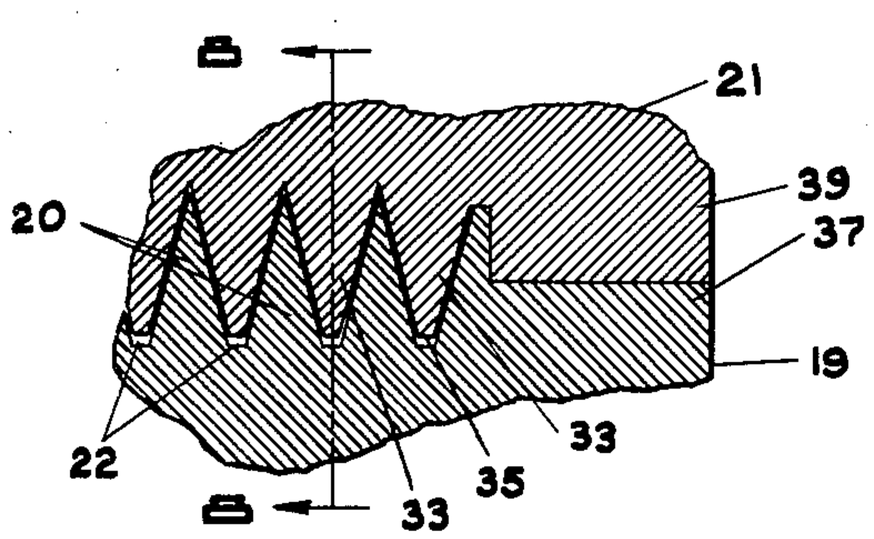


FIG. 8

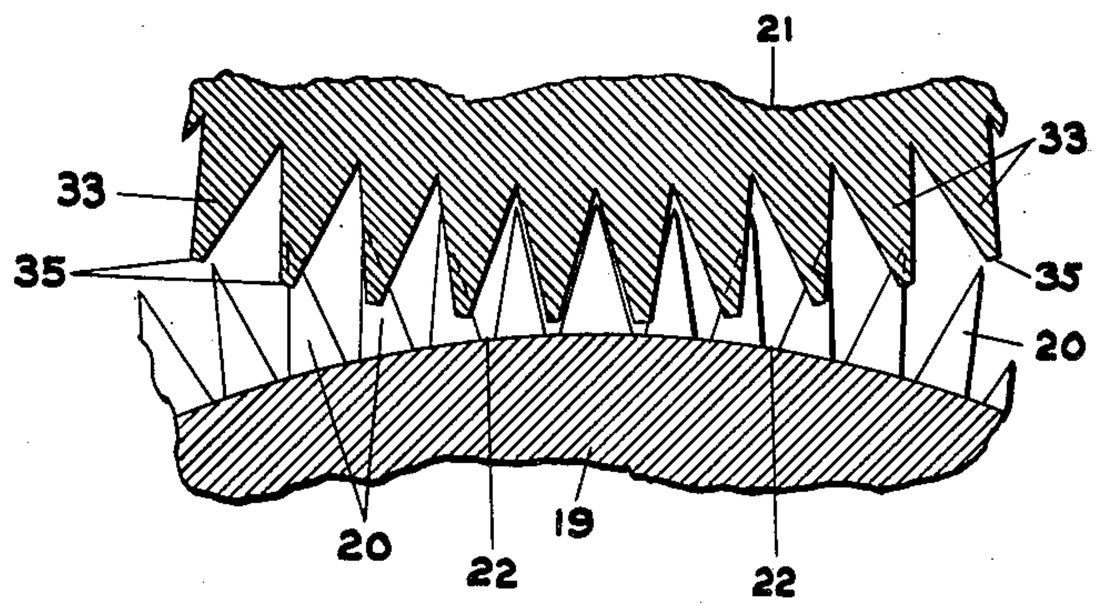


FIG. 9

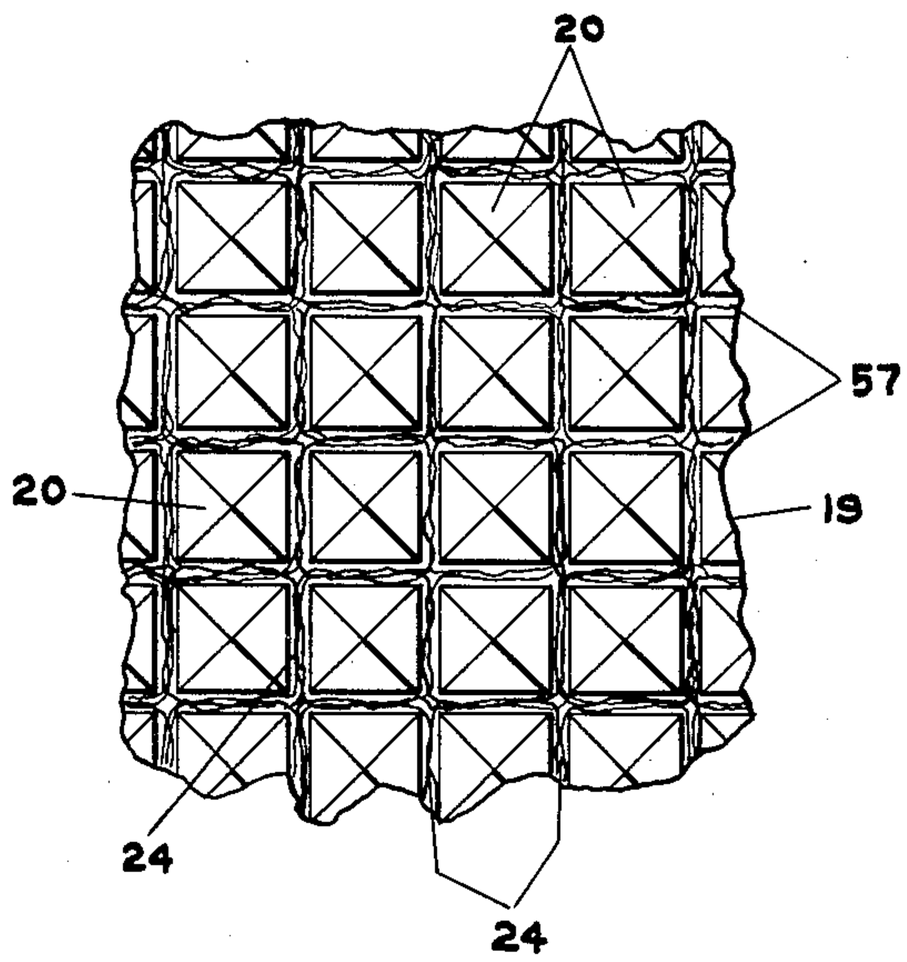
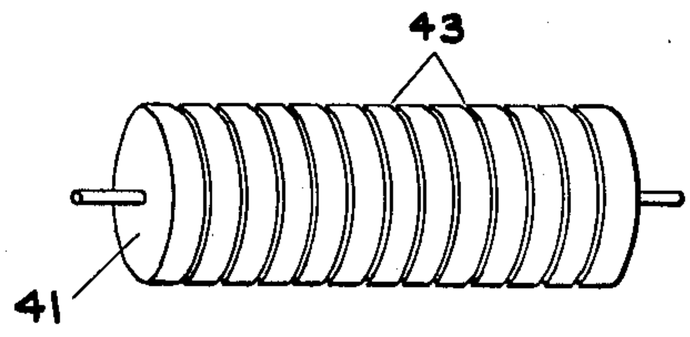


FIG. 10



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United States Patent Office

3,137,893

Patented June 23, 1964

3,137,893
APPARATUS AND PROCESS FOR MAKING APERTURED NON-WOVEN FABRICS

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Filed Dec. 6, 1954, Ser. No. 473,276
10 Claims. (Cl. 18—4)

This invention relates to novel non-woven fabrics and to method and apparatus for making such fabrics. More particularly, this invention relates to non-woven fabrics which are characterized by concentrations or bundles of fibers in definite patterns, whereby new and unique properties are obtained in addition to many of the beneficial properties of both woven and the heretofore non-woven fabrics. These novel fabrics are characterized by the arrangement and/or constraint of fibers into a pattern of intersecting lines, the areas between said lines being substantially free of fibers, or being substantially thinner in said areas than in the concentrated areas.

Since ancient times, fabrics have been prepared by spinning and twisting fibers into yarns and weaving, netting, knitting, or braiding, etc., the yarns into textile fabrics. These processes are slow and expensive, involving many operations, the use of many and complicated machines and much labor. Knitting, braiding, weaving, and like processes integrate the yarns into coherent structures by causing yarns to pass around one another. This results in extra thickness of yarns at points where the yarns going in one direction pass over the yarns going in the other direction. Of course with this type of construction, except in netting, there is considerable freedom, enabling the yarns to slip or slide over or by one another.

In the past, the making of lightweight woven fabrics of the type used for surgical gauzes, curtain fabrics, mosquito netting, tea bags, interlinings and the like has conventionally involved the aforementioned costly and troublesome steps of weaving, knitting, braiding or the like. Because of the light and flimsy construction of these fabrics, they are extremely difficult to handle in the weaving and subsequent steps without biasing, fraying or otherwise disturbing the orderly arrangement of yarns. Furthermore, any cutting or slitting of this type of woven fabric is an invitation to distortion, ravelling, or both. A major cause of this instability is the lack of connection of the warp and filling yarns at the intersections thereof.

To avoid the difficulties and expense involved in producing such woven fabrics, numerous attempts have been made to produce fabrics otherwise than by spinning and weaving, etc., of yarns. Thus in certain known processes of making non-woven fabrics from fibers, binders are applied to hold the fibers together in a coherent sheet. This is done, for example, by spraying or dipping webs of fibers in solutions, dispersions or emulsions of cementitious substances and then drying the webs into the desired structure. Alternatively, a binder in power form may be applied to the web which may then be treated by heat or by a suitable solvent to activate the binder. Products which are produced by these methods usually are undesirably boardy and stiff.

It has also been proposed to apply the binder to a continuous uniform web of textile fibers by printing or spraying it in a pattern of lines or disconnected spots. This is said to have some advantage in greater flexibility in the end product. However, because of its continuous sheet-like nature, its applications are seriously limited, particularly as a substitute for woven fabric.

Fibers of paper-making length and paper-making methods of forming waterlaid sheets have also been proposed for making substitutes for woven fabrics. In general, these produce very weak or very stiff, rigid and paper-like products.

Of course, the products produced by assembling yarns as by weaving, knitting and the like have certain superior characteristics over the hitherto known structures produced by binding fibers into non-woven sheets. In speaking of non-woven sheets in this regard I include products made from textile length fibers as well as products made of non-textile length fibers. For example, fabrics which are prepared by assembling yarns as by braiding, knitting, netting, weaving and the like, have greater strength, limpness, durability and drape, and have an inherent ability to yield in the bias direction. On the other hand, they have certain disadvantages as compared to non-woven fabrics, particularly in the matter of cost as previously pointed out. Moreover, non-woven fabrics can be made almost indefinitely thin and light, which affords advantages to the non-woven fabrics not only in the matter of cost, but frequently in the matter of utility. This lightness and what I will call economy of production, may be obtained without introducing problems of fray, slippage, ravelling, snagging and the like which are generally associated with products produced from an assembly of yarns.

In order to overcome many of the difficulties of both the woven and the heretofore known forms of non-woven fabric, a leading object of the present invention is to devise a novel apertured non-woven fabric.

Another important object of the invention is to make an apertured fabric without substantial loss or cutting of the component fibers.

A further object of the invention is to produce a flexible non-woven fabric which may be made yieldable in a bias direction, if desired.

Another object is to produce a directionally stiff non-woven fabric, if desired.

Another object of the invention is to produce a non-woven fabric in which the different areas of the same fabric display different qualities and physical characteristics, such as varied porosity and different configurations contiguously or of different thickness.

A still further object of the invention is to produce a mechanically strong-non-woven fabric having properties which are similar to conventional fabrics made from yarns.

Another object of this invention is to provide a non-woven fabric in which the fibers are associated into a non-woven structure simulating yarns.

Another object of this invention is to provide a non-woven fabric in which the fibers are associated into simulated yarns which may be disposed at selected angles with other simulated yarns and in which there may be two or more direction sets of simulated yarns.

Another object of this invention is to provide a non-woven apertured fabric which is composed of simulated yarns which coalesce at their points of intersection.

Another object of this invention is to provide a simulated woven fabric in which the thickness of the fabric at the intersections of simulated yarns is not substantially different from the thickness between said intersections of simulated yarns.

Another object is to provide a fabric containing simulated yarns and intermediate areas having fewer fibers per unit area than do the pseudo yarns.

Another object of this invention is to provide an apertured permeable open fabric which is highly resistant to fray and ravelling.

Another object of this invention is to produce a non-boardy fabric.

Another object of this invention is to provide a continu-

ous process for producing an apertured non-woven fabric.

A still further object of this invention is to provide apparatus for producing an apertured non-woven fabric.

Still further objects and advantages of the invention will appear from the following description and appended claims. Before explaining in detail the present invention, however, it is to be understood that the invention is not limited in its application to the details described herein, since the invention is capable of other embodiments and of being produced or practiced or carried out in various ways.

I have discovered that a novel apertured fabric of unspun and unwoven fibers may be produced in accordance with my invention by forming the fiber into a substantially continuous web of predetermined unit weight and of indeterminate length; forming apertures of predetermined shape, position and size in the web by displacing the fibers from the aperture locations to the marginal areas separating the apertures to form individual fibers into a zig-zag conformation about the apertures; applying binder material at selected areas of the web either before or after the apertures have been formed; and selectively setting some or all of the binder-treated areas after the apertures are formed. In accordance with this embodiment, the fibers may be displaced to form the apertures by such means as by directing streams or jets of gas or liquid at the web which is suitably supported by a porous support, said jets being directed in localized areas and with sufficient velocity to displace the fibers in a predetermined pattern. Also in accordance with this embodiment, the fibers may be displaced to form the apertures by forcing bosses, studs, pins, or the like through the web so as to displace the fibers and create the desired pattern of apertures without substantially cutting the fibers. A continuous method of performing this operation will be more fully described hereinafter.

Alternatively, and also in accordance with my invention, the apertured fabric may be produced by forming the apertures as the web is being assembled. One way of accomplishing this is to disperse fibers in air or water; direct the dispersion to a screen patterned with impervious areas which act as resists; collect the fibers on the screen by some suitable means, as for example by providing suction behind the screen; remove the dispersant and thereby deposit an apertured web on the screen. In accordance with this embodiment, a cementitious binder material is applied to the web either during the web formation step or after the web is formed. When the binder is applied during the web formation step it may be added to the suspension or may be added by providing between 0 and 100% of binder fiber with the other (non-binder) fiber making up the balance of the total fiber components of the dispersion. In this regard, when I speak of binder fibers, I mean those fibers which may be softened by heat or solvent action to become adhesive either to themselves or with the non-binder fibers or both.

The fibers which surround the apertures of the fabric of my invention are aggregated into patterns which simulate yarns. The stability and integrity of the fabric is derived from the cooperation of the fibers and cementitious substances with which they are bonded to form yarn-like structures in the fibrous areas of the fabric. These fiber-containing areas serve functions similar to those of the conventional spun yarns in woven, knitted or the like fabrics and, therefore, for a better term I refer to these fiber-containing portions of my fabric as simulated or pseudo yarns. Unlike ordinary spun yarns, however, the pseudo yarns of my invention may be made to coalesce at points of intersection with other pseudo yarns.

It will be apparent to those skilled in the art that a great variety of fabric patterns may be obtained from the practice of my invention. By varying the size, shape and location of the apertures and/or the location of the concentrations or bundles of fibers forming the pseudo yarns in the fabric, a legion of fabrics having different and, in some instances, unusual physical and decorative

properties may be produced. For example, the apertures may be made substantially square, in which event the pseudo yarns will be directed in straight lines and at substantially right angles to each other. Such a fabric would find use in many applications in which woven fabrics are now required, such for example, as in surgical gauze. On the other hand, the apertures may be made circular or elliptical or heart-shaped or clover-shaped, or any one or more of the infinite number of shapes in which one or more members is an arcuate member. Such a material would find use as a decorative fabric as well as a general utility fabric. Furthermore, the apertures may be made in one or more regular or irregular polygonal shapes such as oblongs, diamonds, triangles, pentagons, hexagons, etc., to form a fabric which has uni- or multi-directional stability or strength-forming lace-like arrays. The apertures of the fabric made in accordance with my invention may be of two or more different shapes. Similarly the size or location of any given shaped aperture may be varied in the same fabric. By the same token the pseudo yarns may extend substantially continuously in a given direction or maybe interrupted by coalescence with pseudo yarns having a different direction, thus giving an appearance similar to that of the mortar bonds of a brickwork pattern.

The fiber bonding may be general, as for example, where all the fibers of all of the pseudo yarns are bonded to other fibers in the pseudo yarns; or may be localized as, for example, where intersecting pseudo yarns are bonded only at all or some of their points of intersection with other pseudo yarns or in areas between said points of intersection. Similarly, the points of bonding the fibers in pseudo yarns may follow regular or irregular patterns or may be indiscriminate. It is also contemplated to be within the scope of my invention to bond all of the fibers of all of the pseudo yarns passing in one direction, while leaving the fibers of the pseudo yarns passing in the other direction substantially unbonded except, of course, at the points of intersection with the bonded pseudo yarns of the fabric. By this last-mentioned embodiment of this invention, it is possible to produce stable, strong but directionally stiff fabrics in which the pseudo yarns passing in one or more directions are reinforced with bonding agent, while the pseudo yarns in other directions are intermittently bonded.

The bonding medium may be applied in the liquid form by means of solutions, suspensions, emulsions or latices as by spraying, padding, dipping, licking, brushing, painting, coating or by other methods which are well known in the arts, followed by removal of the liquid vehicle by evaporation. If desired, or if required for the development of the adhesive properties of the binder, the fabric may be heated by infra-red rays, hot air or heated rolls with or without pressure in order to firmly bond the fibers with the cementitious materials. Among the bonding agents which may be used are the polyvinyl chlorides, polyvinyl acetate and copolymers thereof; cellulose acetates, butyrates and nitrates; acrylic resins; natural or synthetic rubber latices; polyester resins; alkyd resins; polyamides; starches, glue, shellac, polyvinyl alcohol and the like.

An alternative method of binding the fibers together is to use a solution or a dispersion of a polymerizable substance in a low degree of polymerization or resins which may be cured or cross-linked, and to apply the substances to the web either before or after the formation of the pseudo yarns. The resin precursor or curable or cross-linkable substance is applied either over the whole area of the pseudo yarns or in a predetermined intermittent or discontinuous pattern. The solvent or dispersing agent is then removed. The resin precursor or cross-linkable substance is then polymerized or cross-linked by heat or by other suitable means either over the whole area or in such selected areas as desired and any excess unpolymerized or uncured binder material may then be removed by washing or otherwise. Suitable materials for binders include the urea, phenolic or melamine resins, epoxy resins, polyesters, natural and synthetic rubber latices, and other

film-forming latices such as polybutyl acrylate or vinyl acetate or vinyl chloride-acetate copolymers, polyvinyl butyral and the like.

Another method for applying the binders in accordance with my invention is to dust solid resin particles such as polyvinyl acetate, polyvinyl chloride, shellac, cellulose esters, solid vegetable gums, etc., onto or into the web and activate by heat or by the application of a solvent or swelling agent as is known in the art. When applying binders in the solid form, I prefer to use them in the form of fibers and to blend them into the web before or during the web formation step. Among the binder fibers which can be employed for this purpose are the cellulose esters including cellulose acetate, cellulose nitrate, polyvinyl acetate, polyvinyl chloride, the copolymers of vinyl chloride and acetate, poly acrylonitrile, polyamid fibers and other well-known synthetic fibers.

In the practice of my invention I prefer to use fibers which because of the large ratio of their length to diameter may be handled in textile machinery and are usually referred to as textile length fibers. Usually such fibers are ⅜" in length or longer. However, it is also contemplated to be within the scope of my invention to use fibers of paper-making length which are shorter than the aforementioned textile length fibers. It is also contemplated to be within the scope of my invention to include short pieces of thread or yarn in admixture with the fibrous material to impart greater strength to the structure. Also, mixtures of textile length fibers and paper length fibers may be satisfactorily employed. Of course the length of the fiber employed will be taken into consideration in determining the distance betwen points of bonding in the pseudo yarns, so that fibers will extend continuously therebetween. That is to say, if shorter fibers are employed the distance between points of bonding would be less than the distance between points of bonding where longer fibers are employed. Among the fibers which may be used in forming pseudo yarns in accordance with my invention are cotton, wool, ramie, hemp, flax, jute, hair, wood fiber, asbestos, glass, vinyl fibers, acrylic fibers, polyamids, polyesters and many others.

Some of the more salient characteristics and objects of this invention will better be understood and appreciated from the following description of one preferred embodiment of apparatus for producing one form of the product of my invention selected for the purpose of illustration and shown on the accompanying drawing in which:

FIGURE 1 shows in diagrammatic manner, the preferred form of apparatus adapted continuously to produce one form of my non-woven fabric from card webs.

FIGURE 2 is a side elevation and FIGURE 3 an end elevation of the rolls of FIGURE 1 which form the grid and cure selected areas of the fabric.

FIGURE 4 is a perspective view showing a portion of the bottom roll **2** on an enlarged scale.

FIGURE 5 is a developed face view greatly enlarged showing a portion of the surface of the bottom roll of FIGURE 3.

FIGURE 6 is a similar enlarged developed face view of the top roll of FIGURE 3.

FIGURE 7 is a section along line **7**—**7** of FIGURE 3.

FIGURE 8 is a section along line **8**—**8** of FIGURE 7.

FIGURE 9 is an enlarged developed face view of a portion of the bottom roll, FIGURES 2, 3 and 4, with the fibrous mat pressed into the depressions thereof, formed into a grid of pseudo yarns.

FIGURE 10 is a perspective view of a supplemental pressing and curing roll of FIGURE 1.

FIGURE 11 is a plan view of my apertured fabric in which the pseudo yarns are arranged to provide diamond-shaped apertures.

Referring to the drawings and more particularly to FIGURE 1, wherein for the purpose of illustration is shown the preferred embodiment of my invention, a random web or fleece **3** comprised of fibers and built up to the desired thickness by superimposing the webs from

a plurality of carding machines **5** is conducted by an apron **7** traveling around rollers **9** into a chamber **11** and is fed through a nip of a pair of rollers **13** and **15**. The latter roll **15** is the applicator roll which rotates in a bath **17** of a suitable binding material, preferably containing or comprising heat curing resin such as urea formaldehyde resin of a suitable molecular weight containing a catalyst, thus supplying a quantity of the binder to the roll surface for transfer to and saturation of the moving web **3**. In lieu of the heat curing resin, a heat coagulatable latex such as polyvinyl butyral may be used. The upper roll **13** serves to back up the web as the binder is being forced through the body of the web. Other means of impregnating the web with binder such as spraying or dipping, and the use of two screen aprons confining the web between them are, of course, contemplated.

The fibrous web **3**, thus impregnated with binder, leaves the endless apron **7** upon emerging from chamber **11** and thence passes over a novel roll **19**, FIGURES 1 to 5, 7 to 9, the endless supporting surface of which is covered with sharp pyramidal pointed elements or projections **20** disposed in circumferential and longitudinal lines with intervening interconnected grooves or valley elements **22**, whose bottoms are all equally distant from the axis of the roll. The points **20** are made sufficiently sharp at their free ends and are tapered with the angles of their side walls so acute and with their transverse cross sectional area increasing progressively from their free ends radially inward so that the points will engage with the web so as to pass freely through the web **3** and displace the fibers they engage and thus form the web into a grid or lattice-like configuration of pseudo yarns **24**, with fibers extending continuously between the points of intersection, as shown in FIGURE 9, without substantial breakage, cutting or loss of the fibers initially present in the web. It is to be understood that these points **20** are shown greatly exaggerated in the drawings for clarity, but that they must be tapered and their height over the grooves or valley elements must be substantially greater than the thickness of the web, as shown in FIG. 1, and that their transverse dimensions and spacing must be substantially less than the length of at least a substantial proportion of the individual fibers of the web, as shown in FIG. 9, to provide the desired zig-zag conformation of the fibers.

To insure that the fibrous mat or impregnated web is properly laid into the longitudinal and circumferential mutually intersecting valleys **22** of the bottom roll **19**, a suitable depressing means is employed which in this embodiment consists of an inverted T-shaped air manifold **23** extending along and above the roll **19**. The manifold has a series of nozzles **25** wherefrom air jets directed toward the roll surface successively force the continuously moving fibrous mat impaled on the points downward as it passes the jets, to penetrate the web and to move it downward between the sharp points **20** along the sides thereof into the valleys **22** of roll **19** to divert the fibers of the web into a zig-zag conformation around the points **20** to form the lattice-like mat of pseudo yarns, providing apertures in a predetermined pattern corresponding to the pattern of the points **20**, this action being aided by gravity.

The thermo-setting resin binder in the fibrous material so positioned on the roll is then cured to bond the fibers at each intersection of the valleys **22** by a heated presser roll **21** which rotates on a fixed axis about shaft **31** and is provided as seen in FIGURES 3, 6, 7 and 8 with pyramidal elements **33** with truncated tops **35** which project into the circumferential valleys **22** of roll **19**.

The two rolls **19** and **21** are provided with cylindrical end potrions **37**, **39**, free from pyramids, which are in rolling contact with each other, thus forming bands determining the spaced relation between the opposing sets of points **20**, **33** as the rolls rotate concurrently. Thus a space is left between the bottoms of each circumferential valley **22**, the flat tops **35** of the points **33** entering such valley, FIGURES 7 and 8. In this space the fibers of

the grid **24** are subjected to pressure which is restricted to a moderate amount by the riding band **37**, **39** and localized solely at the points at intersections of the bars and of the grid because the two rolls **19** and **21** are geared together and driven in unison to cause the truncated tops **35** of the points **33** to fall only at the intersections of the circumferential and longitudinal valleys **22** of roll **19**. The pyramids of one roll do not engage those of another apart from accidental end play of the shafts **29**, **31**; ideally they operate as in FIGURES 7 and 8. The top roll **21** may be heated herein by steam injected through its hollow axle **31** while roll **19** is unheated and thus the binder permeating the grid is cured only if set at the intersections as a result of the heat and pressure applied by flat-tops **35** of the points of the top roll **21**.

As indicated in FIGURE 9, the sharp points **20** of the bottom roll **19**, in penetrating the web, divert the component fibers thereof, except such as chance to already be aligned with the valleys **22**, out of their initial line so that they bend around the corners of the pyramids **20** and thus each of these initially oblique or curving fibers extends in a zigzap relation, first circumferentially and then longitudinally of the roll or vice versa, or in other words both lengthwise and crosswise of the resulting fabric, in the plane of the fabric to form pseudo yarns, the fibers being substantially longer than a side of one of the pyramdis, plus the spacing between adjacent pyramids, so that many of them extend continuously between adjacent pseudo yarn intersections.

The resulting apertured web is continuously removed from roll **19** and fed by guide roll **10** into a chamber **45** in which the uncured or uncoagulated binder material which lies in the portions of the grid apart from the cured intersections is removed by a suitable bath containing a solvent or other washing medium and the web **3** then passes into a drying chamber **49** which removes the solvent or washing medium. The dry fabric upon emerging from such latter chamber is wound into roll **47** by any suitable or preferred means.

Production of such fabric by the described curing of the binder at the intersections **57** only with unbonded fiber portions extending therebetween for fabric integrity produces a material characterized by a higher degree of flexibility, softness, drape and absorbency than apertured fabrics in which the entire length of all the component fiber is left coated with binder. To produce even softer fabrics according to the invention, it is contemplated in certain instances to cure less than the total number of intersections by eliminating certain of the points **33** of the top roll **21** as well as for both esthetic and practical effects to cure the intersections in arbitrary sequence to form decorative patterns or to have different parts of the same fabric display different qualities as for bandage purposes. In this way portions of the rolls **19**, **21** may be so designed that they will produce non-woven fabrics of varied porosities, physical characteristics and configurations contiguously and out of the same parent fibrous mat.

To make fabrics of a different nature, the entire grid **24** of the fabric may be cured. To do so according to the invention, web **3** from between the spike rolls **19**, **21** in apertured form with the intersections cured is fed between smooth surface rolls corresponding in position and action to rolls **40**, **41**, FIGURE 1, both heated. Substantially all the binder present in the web is thus cured. By alternatingly applying and relieving the pressure of rolls **40**, **41** as by raised or sunken areas from their surfaces, one portion of the fabric can remain uncured, while another portion is cured throughout its entire area.

It is also contemplated to cure the entire extent of either the longitudinal or transverse elements **24**, but not both, of the apertured web in certain instances to provide directionally stiff fabrics suitable for use, for example, as clothing interlining. To produce a transversely stiffened fabric of this sort the web **3** upon emerging from between the spike rolls **19**, **21** in apertured form with the intersections cured is fed between press rolls **40**, **41** heated after the manner of roll **21**, of which at least one roll **41** is formed with circumferential grooves **43** registering with longitudinal elements of the grid **24** as the web **3** passes between these rolls. Thus the binder present in the transverse elements is cured throughout the intervals between the previously cured intersections by the heat and pressure of the rolls, while the longitudinal elements traveling in the grooves **43** of roll **41** escape the pressure and are insufficiently heated to cure the binder, such uncured binder being removed from the fabric in the washing chamber **45** leaving these portions in their original state. Similarly, by using in place of roll **41** a roll which has only longitudinal grooves that are spaced apart by the same interval as the transverse elements of the apertured web **24**, this roll being synchronized with spiked roll **21** through intermediate gears **46**, **48** so that these longitudinal grooves will register with the transverse elements of grid **24**, the latter elements are left uncured and the longitudinal elements are cured to produce a longitudinally stiff fabric. As before, these uncured fibers of the transverse elements are washed free of resin in chamber **45** and are thereby returned to their original state. As already indicated, these uncured portions of the fabric remain more absorbent and flexible than the cured portions of the lattice and may be so treated as to exhibit almost any desired characteristics.

Additionally, where it is desired to produce a fabric having a texture simulating more closely a woven material, the apertured fabric in the form first described herein and having fibers bound only at the intersections of the elements of the grid may be treated with a shrinking agent or other known suitable media adapted in well-known manner to shrink the fabric and thus reduce the size of the voids produced by the points **20** or even to close them entirely so that the resulting fabric appears to be constructed of warp and weft yarns. Examples of this would include the use of caustic with cotton fibers or the use of heat with stretched synthetic fibers. Applying this step to the novel fabrics in the cases where the binder is cured at less than all the intersections, as in the form of a pattern or design, enables a close simulation of various figured fabrics produced by weaving.

Where in forming a coarse apertured fabric the valleys **22** of the spiked roll **19** are wide enough to permit it, a depressed roll having thin circumferential fins adapted to enter the bottom of the circumferential valleys **22** of roll **19** and force the web **3** down over the pyramids may be used in certain instances. Cooling of the non-heated rolls can be done in a suitable manner such as by circulating cooling water within the roll via hollow axles after the manner employed to heat rolls **21**, **41**.

I have found that the apertured fabrics of my invention can be used to substitute for conventional woven or knitted fabrics in many end uses and for many other purposes are to be preferred to woven fabrics.

Sanitary napkins are usually covered with a low-count surgical-grade gauze, although some brands are covered with a non-woven fabric having a continuous and uninterrupted surface. It is well known that gauze is prone to fray badly by slippage of the filling yarns and gathering into groups or ropes. The presently-used non-woven fabric of continuous surface has been found to have too small a pore size and is widely criticized as hindering the passage of drainage into the interior of the pad. The apertured fabric of my invention is free of the tendency to fray as has heretofore been explained and the size and frequency of the apertures can be chosen so as to facilitate passage of drainage while at the same time confining the bulk absorbent with which the pad is filled.

Certain surgical dressings, as for example, surgical sponges and fluffs, are composed of many layers of a very light-weight woven gauze folded with great care so as to bury all cut edges. It has been found that this type of structure is greatly to be preferred over one composed of few layers of a heavier or more closely woven

fabric. The aggregation of fibers into yarns separated by holes which are many times the width of the yarns comprises a structure which performs well in quickly absorbing the drainage accompanying surgery or resulting thereafter. My apertured fabric may be constructed in close imitation of the structure of surgical gauze and can perform as such with the added advantages of freedom from ravelling at cut edges, substantial freedom from fray, and better anchorage of the fibers in the pseudo yarns.

Window curtains are frequently made of scrims, voiles and more complicated fabrics which have a varied pattern of openings between yarns and are called laces, these laces being made on complicated machines operated at slow speeds. My apertured fabric may readily be made to have openings of any chosen size or decorative selection of pattern so as readily to admit light and air and present a pleasing appearance. Many curtain fabrics are made with what is called a leno weave so as to control the yarn slippage and fray which is frequent with low-count fabrics and is particularly undesirable in so conspicuous an article of household decoration as a curtain. Again, my apertured fabric is particularly resistant to fray and useful in this connection.

The highest quality and most expensive mosquito nettings are made from a marquisette cloth having a leno weave to control the uniformity of the size of openings, in order to prevent the passage of insects. Cheaper cloths of a plain (in contrast to a leno) weave are often used used for this purpose in order to save cost, but are substantially less satisfactory because of the intrinsic tendency to fray. My apertured non-woven fabric is peculiarly well designed to obviate both the problems of expense and of fray.

In the clothing industry use is made of woven fabrics which are designed so as to be stiff in one direction while maintaining substantial limpness in the other direction. These have been constructed by coalescing the filling yarns by use of cellulose solvents, in a fabric in which warp yarns are resistant to such solvating action. Such fabrics have also been made by a very dense packing of heavy yarns in one direction. Both types of fabric have been very expensive to make. By heavily bonding the pseudo yarns of my apertured non-woven fabric in one direction while providing the pseudo yarns in the other direction with little bonding or for that matter in some extreme cases leaving the pseudo yarns in the other direction wholly unbonded, a directionally stiff fabric may readily and cheaply be obtained. Another form of my apertured non-woven fabric having directional stiffness is one in which the fibers are substantially oriented in one direction in preference to the other or one in which the pattern of the apertures is so chosen as to form heavy pseudo yarns in one direction and light pseudo yarns in the other direction.

Frequently woven fabrics are required to bear heavy loads in one direction. Examples are fabrics for use in power belting, belts for clothing, tapes, etc. Apertured non-woven fabrics so constructed as to have heavy pseudo yarns in one direction are ideally designed for these purposes. Particularly in a laminated structure where the apertured non-woven fabric is embedded in a solid matrix, my fabric will produce more strength in the finished article than will conventional woven fabrics of the prior art. Woven fabrics are composed of yarns which owe their integrity to twisting. The angle of the twist puts the fibers at a mechanical disadvantage when stress is placed on the yarn. The pseudo yarns of my novel fabric are without twist and can therefore make effective the full strength of the constituent fibers.

Woven fabrics, particularly those not closely woven, can be extended very easily in the bias direction; my apertured non-woven fabric can be designed so as either to be readily extensible in the bias direction or to resist such extension very strongly. If my apertured non-woven fabric is composed of widely-spaced pseudo yarns simulating warp and filling threads, my fabric will deform easily in a bias direction. By choosing the shape of my apertures so that more than two direction-sets are formed, for example, three at 60° from each other, a fabric which is remarkably resistant to extension in any direction is provided. The bias direction of the apertured non-woven fabric may be made the machine direction of the fabric by making the apertures diamond or lozenge shape as shown by the numeral **55** in FIGURE 11. Bias tapes may then be made by slitting the fabric in the machine direction.

Woven fabrics and non-woven fabrics of the prior art in general have limited elasticity or ability to extend under tensile stresses. This property in the bias direction may be developed in my apertured non-woven fabric to a high degree by construction of the fabric in the manner of the previous paragraph. In cases where marked extensibility of the apertured non-woven fabric is desired, it may readily be provided in the design. For example, if the apertures are made as packed hexagons, the pseudo yarns will not be straight but will be jointed segments of straight lines at an angle of 120° to each other. This tolerance path of the pseudo yarn provides a built-in extensibility. For another example, the apertures may be chosen as squares with their sides not lying in a straight line, giving the appearance of a brick work. This procedure provides marked extensibility in the direction to the fabric in which the pseudo yarns are interrupted.

In the above description of the product of my invention I have restricted the discussion to the preferred product of my invention, which is a product composed of an assembly of pseudo yarns forming an apertured fabric wherein the apertures are substantially devoid of fibrous material. However, it should be understood that it is also in accordance with my invention to provide a fabric consisting essentially of an assembly of pseudo yarns where the apertures are not free from fibrous material. For example, it is contemplated that a fiber-liquid dispersion could be directed to a screen having areas of high porosity in which the pseudo yarns are deposited and areas of lesser porosity on which intermediate areas are deposited, said intermediate areas having fewer fibers than the areas containing pseudo yarns. Products prepared in accordance with this embodiment have many of the desirable properties of the apertured fabric whose apertures are substantially devoid of fibrous material and for certain uses may be more desirable than my preferred product, as for example, as a filtering medium.

While I have illustrated and described certain forms in which the invention may be embodied, I am aware that many modifications may be made therein by any person skilled in the art, without departing from the scope of the invention as expressed in the claims. Therefore, I do not wish to be limited to the particular forms shown, or to the details of the construction thereof, but

What I do claim is:

1. A continuous process for producing apertured non-woven fabric from a fibrous web of indeterminate length, by displacing the fibers of said web into an array of intersecting and coalescing yarn-like bundles defining a pattern of apertures, comprising

engaging said web with the ends of a plurality of projections supported in a predetermined pattern on a support with interconnected valleys therebetween,

the height of said projections being substantially greater than the thickness of said web and the transverse dimensions and spacing being substantially less than the length of at least a substantial proportion of the fibers of the web,

successively forcing said web into said valleys by applying fluid streams to the surface of said web to penetrate said web by said projections and divert individual fibers of said web into a zig-zag conformation around said projections into said valleys and

thereafter continuously removing said web from said projections to form a non-woven fabric having aper-

tures in a predetermined pattern corresponding to the pattern of said projections.

2. A continuuos process for producing apertured non-woven fabric from a fibrous web of indeterminate length, by displacing the fibers of said web into an array of intersecting and coalescing yarn-like bundles defining a pattern of apertures, comprising

engaging said web with the ends of a plurality of projections supported in a predetermined pattern on a support with interconnected valleys therebetween,

the height of said projections being substantially greater than the thickness of said web and the transverse dimensions and spacing being substantially less than the length of at least a substantial proportion of the fibers of the web,

successively forcing said web into said valleys by applying fluid streams to the surface of said web to penetrate said web by said projections and divert individual fibers of said web into a zig-zag conformation around said projections into said valleys while continuously moving the engaged web relatively to said streams and

thereafter continuously removing said web from said projections to form a non-woven fabric having apertures in a predetermined pattern corresponding to the pattern of said projections.

3. A continuous process for producing apertured non-woven fabric from a fibrous web of indeterminate length, by displacing the fibers of said web into an array of intersecting and coalescing yarn-like bundles defining a pattern of apertures, comprising

engaging said web with the pointed ends of a plurality of projecting tapered elements supported in a predetermined pattern on a continuously moving support, said projecting tapered elements having a cross sectional area increasing downwardly from the free ends thereof and being spaced to provide interconnecting valleys between said projecting elements,

the height of said projections being substantially greater than the thickness of said web and the transverse dimensions and spacing being substantially less than the length of at least a substantial proportion of the fibers of the web,

successively forcing the fibers of said web into said valleys by applying fluid streams to the upper surface of said web to penetrate said web by said projections and divert individual fibers of said web into a zig-zag conformation around said projections into said valleys while continuously moving the engaged web relatively to said streams and

thereafter continuously removing said web from said projections to form a non-woven fabric having apertures in a predetermined pattern corresponding to the pattern of said projections.

4. A continuous process for producing apertured non-woven fabric from a fibrous web of indeterminate length, by displacing the fibers of said web into an array of intersecting and coalescing yarn-like bundles defining a pattern of apertures, comprising

engaging said web with the pointed ends of a plurality of projecting tapered elements supported in a predetermined pattern on a continuously moving support, said projecting tapered elements having a cross sectional area increasing downwardly from the free ends thereof and being spaced to provide interconnecting valleys between said projecting elements,

the height of said projections being substantially greater than the thickness of said web and the transverse dimensions and spacing being substantially less than the length of at least a substantial proportion of the fibers of the web,

successively forcing the fibers of said web into said valleys by applying fluid streams to the upper surface of said web to penetrate said web by said projections and divert individual fibers of said web into a zig-zag conformation around said projections into said valleys while continuously moving the engaged web relatively to said streams,

bonding at least a portion of the fibers of said web while said fibers are maintained in said valleys and

thereafter continuously removing said bonded web from said projections to form a non-woven fabric having apertures in a predetermined pattern corresponding to the pattern of said projections.

5. Apparatus for continuously producing apertured non-woven fabric from a fibrous web of indeterminate length, comprising

an endless support having a surface carrying a plurality of projections in a predetermined pattern with interconnected valley elements therebetween,

the height of said projections over said valley elements being substantially greater than the thickness of said web and the transverse dimensions and spacing of said projections being substantially less than the length of at least a substantial proportion of the fibers of the web,

web depressing means for forcing said web into said valley elements, comprising fluid means directed toward said surface, and

means for removing the apertured web from said valley elements and said projections

whereby said web of fibers will be penetrated by said projections and the individual fibers of said web diverted into a zig-zag conformation around said projections into said valley elements to form a non-woven fabric having apertures in a predetermined pattern corresponding to the pattern of said projections.

6. Apparatus as claimed in claim 5, wherein said endless support is a roll.

7. Apparatus for continuously producing apertured non-woven fabric from a fibrous web of indeterminate length, comprising

an endless support having a surface carrying a plurality of projections in a predetermined pattern with interconnected valley elements therebetween, said projections having pointed ends and being tapered with their cross sectional area increasing progressively from their free ends inwardly,

the height of said projections over said valley elements being substantially greater than the thickness of said web and the transverse dimensions and spacing of said projections being substantially less than the length of at least a substantial proportion of the fibers of the web,

web depressing means for forcing said web into said valley elements, comprising fluid means directed toward said surface and

means for removing the apertured web from said valley elements and said projections

whereby said web of fibers will be penetrated by said projections and the individual fibers of said web diverted into a zig-zag conformation around said projections into said valley elements to form a non-woven fabric having apertures in a predetermined pattern corresponding to the pattern of said projections.

8. Apparatus for continuously producing apertured non-woven fabric from a fibrous web of indeterminate length, comprising

an endless support having a surface carrying a plurality of projections in a predetermined pattern with interconnected valley elements therebetween,

the height of said projections over said valley elements being substantially greater than the thickness of said web and the transverse dimensions and spacing of said projections being substantially less than the length of at least a substantial proportion of the fibers of the web,

web depressing means for forcing said web into said valley elements, comprising fluid means directed toward said surface,

means for bonding said web while it is maintained in said valley elements and about said projections comprising

a support having a plurality of depressing elements extending into said valley elements between said projections and

means for removing the bonded apertured web from said valley elements and said projections

whereby said web of fibers will be penetrated by said projections and the individual fibers of said web diverted into a zig-zag conformation around said projections into said valley elements to form a non-woven fabric having apertures in a predetermined pattern corresponding to the pattern of said projections.

9. Apparatus as claimed in claim 8, wherein both said supports are rolls.

10. Apparatus for continuously producing apertured non-woven fabric from a fibrous web of indeterminate length, comprising

a roll carrying a plurality of projections in a predetermined pattern with interconnected valley elements therebetween, said projections having pointed ends and being tapered with their cross sectional area increasing progressively from their free ends inwardly,

the height of said projections over said valley elements being substantially greater than the thickness of said web and the transverse dimensions and spacing of said projections being substantially less than the length of at least a substantial proportion of the fibers of the web,

web depressing means for forcing said web into said valley elements, comprising fluid jet means directed toward said roll,

means for bonding said web while it is maintained in said valley elements and about said projections comprising

a supporting roll having a plurality of depressing elements extending into said valley elements between said projections and

means for removing the bonded apertured web from said valley elements and said projections

whereby said web of fibers will be penetrated by said projections and the individual fibers of said web diverted into a zig-zag conformation around said projections into said valley elements to form a non-woven fabric having apertures in a predetermined pattern corresponding to the pattern of said projections.

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