April 25, 1950 H. E. HOLCOMB 2,505,045

FILAMENTARY PRODUCT AND METHOD OF ITS PRODUCTION

Filed July 27, 1948 2 Sheets-Sheet 1

Fig. 1.

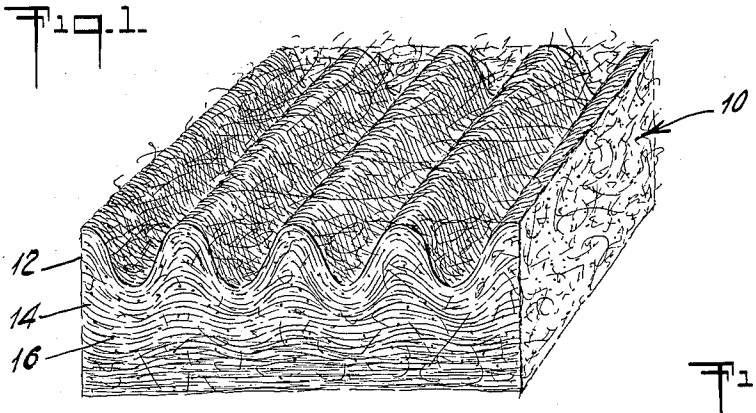


Fig. 2.

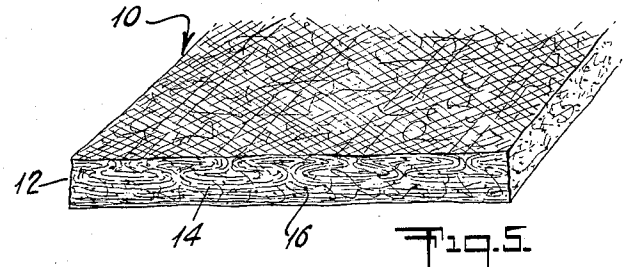


Fig. 3.

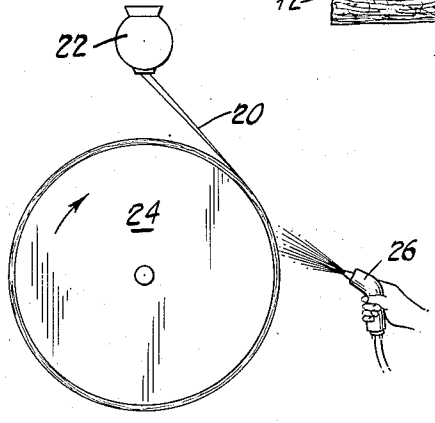


Fig. 5.

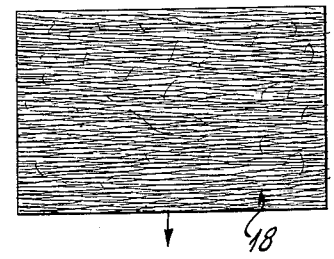
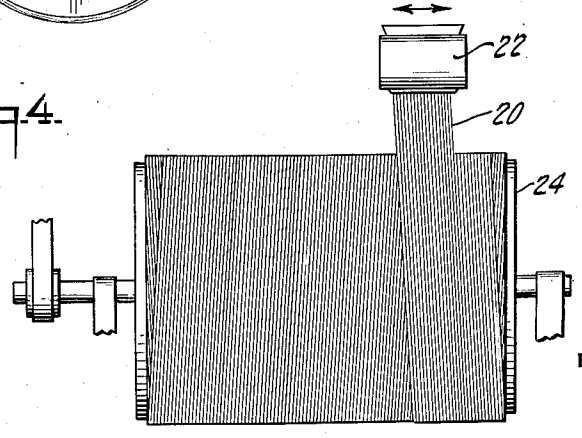


Fig. 4.



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FILAMENTARY PRODUCT AND METHOD OF ITS PRODUCTION

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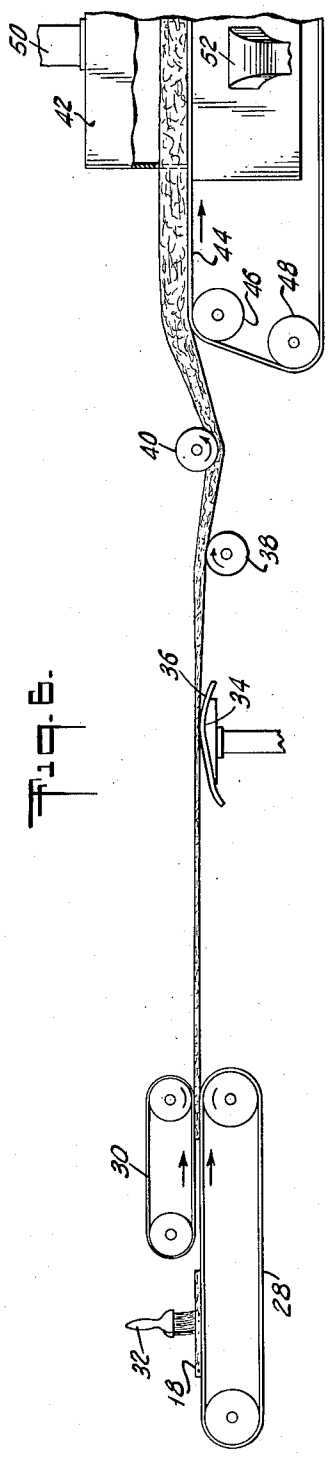


Fig. 6.

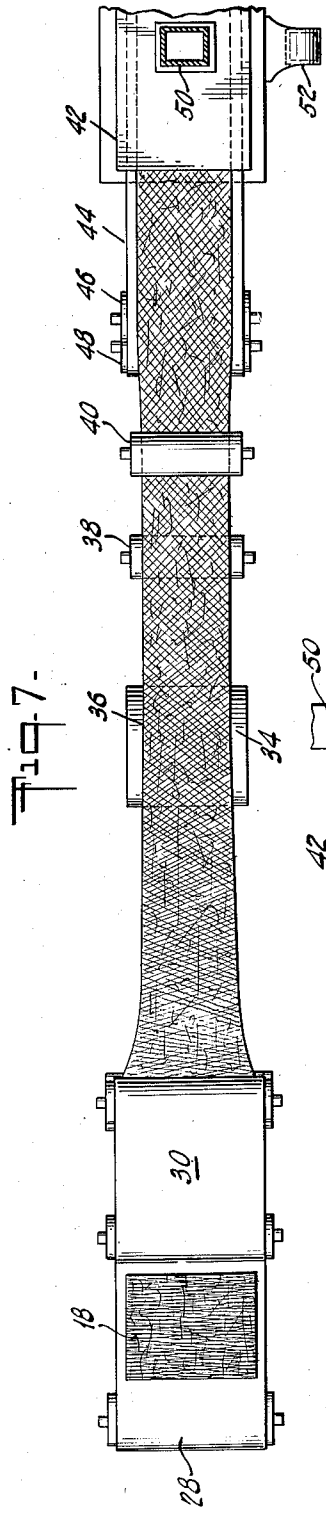


Fig. 7.

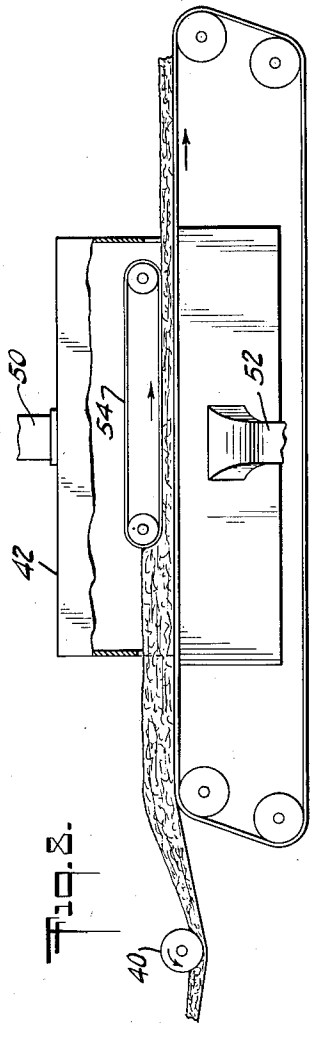


Fig. 8.

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Patented Apr. 25, 1950 2,505,045

UNITED STATES PATENT OFFICE

2,505,045

FILAMENTARY PRODUCT AND METHOD OF ITS PRODUCTION

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Application July 27, 1948, Serial No. 40,816

16 Claims. (Cl. 154—124)

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The instant invention relates to improved products made from continuous, or substantially continuous, glass filaments and to the formation of such products. More particularly the invention is concerned with improvements in products resulting from the puffing or expansion of an original mat made up of a plurality of individual layers in which the filaments of each layer lie substantially parallel and the filaments of adjacent layers cross each other at acute angles.

The invention has for its principal object the provision of an improved product of this type of lesser density and more open texture adjacent one surface than the other, the texture and density preferably gradually changing through the thickness of the product from the one condition to the other. The product suitably contains a minor proportion of a binder which retains the filaments thereof in their positions and bonds the whole into a unitary body. The product is of particular utility as an air filter medium. The surface of less density and more open texture is employed as the air entry side of the filter and, as the dust-laden air enters the body, the coarse dust, lint and the like are removed. As the air passes on through the body the finer dust is progressively deposited, the relatively dense structure adjacent the opposite surface forming a final clean-up section to remove any remainder of the dust. The single unit is thus comparable to a series of filters of varying dust removal characteristics. By removing the coarse dust and lint in the more open section, it is possible to obtain a greatly increased dust retention capacity before resistance to air flow becomes excessive. It will be appreciated, however, that the product may find other fields of usefulness than air filters.

Another object of the invention is the provision of a multi-layer, glass filament mat puffed or expanded in the direction of its thickness comprising a plurality of layers having substantially parallel corrugations or undulations, the undulations being of greater depth and the body of lesser density adjacent one surface, the undulations of the several layers gradually diminishing and the density of the body increasing as the opposite surface is approached.

A further object of the invention is the provision of a method of producing products as defined above.

Briefly stated, the invention resides in a product and method in which a filamentary glass mat composed of a plurality of layers of the filaments

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with the filaments of each layer substantially parallel and the filaments of adjacent layers crossing at acute angles, is drawn or expanded by pulling the mat in a direction substantially at right angles to the general lay of the filaments, the operation being continued until layers of the mat corrugate and the mat as a whole puffs up or expands in the direction of its thickness. In accordance with the instant invention, expansion of the mat is retarded adjacent one surface and is accelerated adjacent the other, whereby the mat puffs to a lesser extent and, hence, is denser adjacent one surface than the other, the intermediate structure of the body varying between the two extremes. Suitably the product contains a binder which is applied in an unset state to the original mat to insure distribution throughout the mat and is set after the expansion operation. Where a product of higher density is desired, the puffed body is compressed and held in that condition during the binder setting operation.

My invention will be more fully understood and further objects and advantages thereof will become apparent when reference is made to the more detailed description of the preferred embodiment of the invention which is to follow, and to the accompanying drawings in which:

Fig. 1 is a perspective view of a segment of an expanded product in accordance with the instant invention;

Fig. 2 is a view similar to Fig. 1 illustrating a modified embodiment;

Fig. 3 is a diagrammatic, end elevational view of an apparatus employed in preparing the initial mat from which the instant structure is derived;

Fig. 4 is a diagrammatic, front elevational view of the apparatus of Fig. 3;

Fig. 5 is a plan view of the mat as made on the apparatus of Figs. 3 and 4;

Fig. 6 is a diagrammatic, elevational view of the apparatus embodying the instant invention;

Fig. 7 is a top plan view of the apparatus of Fig. 6; and,

Fig. 8 illustrates a modified construction of a portion of the apparatus.

Referring now to the drawings, a product of the instant invention consists of a body 10 composed of a plurality of layers 12, each formed of continuous, or substantially continuous glass filaments 14. The filaments of each layer lie in approximate parallelism and the filaments of adjacent layers cross each other. The product is puffed or expanded in the direction of its thick-

ness to produce a lightweight, low density material. In the expanding and puffing operation in accordance with the instant invention, the filamentary layers, particularly those adjacent one surface of the product, the upper surface of Fig. 1, are corrugated and the corrugations are brought into relatively adjacent, lateral relationship. At the same time the corrugated layers are somewhat separated, although tied together by a multiplicity of interconnecting filaments, to form a very low density, open work structure. The corrugations or undulations of the layers inwardly of the surface are gradually of lesser depth as the opposite surface is approached, the layers adjacent the opposite surface being only slightly corrugated or at least having corrugations of relatively shallow depth as compared with the layers adjacent the other surface. The separation between the layers also progressively decreases as the opposite surface is approached and the density of the product proportionately increases.

Intermingled with the filaments of the several layers, and bonding the mass of fibers into a unitary body, is a minor proportion of a binder, say between 5% and 15% by weight of the product. It will be understood that Fig. 1 is diagrammatic and that in actual practice the binder particles illustrated by reference character **16** will be visually insignificant.

The product shown in Fig. 2 is of the same character as that shown in Fig. 1 except in this case the body has been compressed from the thickness shown in Fig. 1 and maintained in compressed state by the set binder. In this embodiment similar gradation of structure of the body is present but the body is proportionately denser throughout.

The products described above are adapted for many uses but are particularly valuable as air filtering media as previously explained. The products are very lightweight and a great multiplicity of fine, intercrossing filaments form a reticulated structure well adapted to remove particulate matter from air or other gases. The gradual increase of density and decrease of the size of the interstices permits a graduated removal of the dust particles, the larger particles being caught or held adjacent the more open side of the filter body. The greatest mass of the particles is removed from the airstream by the intermediate layers and the residue of fine particles which penetrate substantially through the body are collected by the final relatively dense layers. The body may be used in its compressed form, particularly where finer dust particles are present, and exceptional high efficiency is required. In both forms a large filtering capacity is obtained due to the distribution of the deposited dust throughout the body.

Referring now particularly to Figs. 3–8 inclusive, the method and apparatus employed to produce the products described above will be explained in detail. The products are made from the initial mat **18** (see Fig. 5), known as the "condensed mat," fabricated in a substantially conventional manner by drawing a plurality of continuous glass filaments **20** directly from the spinning orifices of the melting furnace **22** and accumulating the filaments on a drum **24**. The drawing drum is rotated in the direction indicated by the arrow in Fig. 3 by any suitable driving means (not shown) and at a relatively high speed to continuously draw fine filaments, say, of 6 to 30 micron diameter, and wind the filaments on the drum. Either the furnace or the drum is reciprocated to lay the filaments on the drum in a plurality of layers of spirals with the filaments of each layer crossing the filaments of adjacent layers. In the apparatus illustrated, the furnace **22** is reciprocated, as indicated by the double-ended arrow in Fig. 4. The rate of reciprocation relatively to the drawing speed, that is the peripheral speed of the drum, is such that the filaments of adjacent layers cross each other at acute angles.

A binder may be applied during the filament drawing operation. This application may be made in any suitable way, for example by a manually operated spray device **26** (see Fig. 3), which is moved back and forth across the mat on the drum at intervals to uniformly spray the binder material onto the mat. The amount of binder used is carefully controlled. As will later be explained in greater detail, only a portion of the total binder content, say up to 70%, is preferably applied at this stage, the remainder of the binder being applied to the mat during later stages in the formation of the product. The total binder used is such that the solids binder content of the finished product is, say, 1 to 5% by weight of the product.

The binder is preferably employed in the form of an emulsion, a water dispersion being suitable. However, a solution of the binder in a solvent may also be employed. The binder may be either thermosetting or thermoplastic, but thermosetting adhesives are preferred. Examples of suitable materials are acrylic resins, urea-formaldehyde resins, polyvinyl alcohols, latices, and the like. In commercial operations it has been found preferable to apply a water dispersion of an acrylic resin during the filament drawing operation and a dispersion of a urea-formaldehyde resin at the later stage. Due to the relatively high speed movement of the mat on the drum and the temperatures prevalent during the filament drawing operation, the binder rapidly dries by evaporation of the water or solvent, as the case may be, so that, upon completion of the drawing operation, the mat contains a substantially dry but unset binder.

When the condensed mat is completed, it is severed along a line of generation of the drum and is removed therefrom. The mat is then placed on a conveyor **28** of a feed device including a conveyor **30** mounted in a suitable manner to overlie the forward end of conveyor **28** and to yieldably engage the latter. While the condensed mat is on conveyor **28** and before it is fed beneath the overlying conveyor, it is treated with a binder softener. In the case of a binder such as the preferred acrylic resin, the softener is water, which in effect again places the finely divided binder in suspension. If binders are employed of the type which cannot be practically softened with water, an appropriate solvent is used. The softener may be applied to the mat in the form of a spray, or a hand brush, illustrated at **32**, may be employed for the purpose. As pointed out above, preferably although not necessarily, only a portion of the total binder content was applied to the condensed mat during the winding operation. Where this practice was followed the remainder of the binder is applied at this time. The added binder may be the same as that already used but suitably is a material such as a urea-formaldehyde resin. This material, in the form of a suspension, is spread on the mat on the conveyor, similarly as the softener. When the mat has been treated as described above, it is

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allowed to stand for an appreciable length of time to permit thorough soaking of the mat.

Referring now specifically to Figs. 6 and 7, the apparatus for expanding the mat, prepared as explained above, will be described. This apparatus, in addition to feed conveyors 28 and 30, previously mentioned, includes in its preferred embodiment, a substantially level table or plate 34 having a forwardly and downwardly angling side flange 36, a lower roll 38 and an upper roll 40. Rolls 38 and 40 are supported to be driven at regulated speeds by suitable means (not shown). An oven 42 is provided forwardly of the rolls, the oven including a conveyor 44 supported at the rear end by pulleys 46 and 48 for movement in the direction indicated by the arrow by any suitable driving means (not shown). The forward end of the oven conveyor will be similarly supported. The conveyor is of open, gas pervious construction and suitably may be made of wire mesh material. Means are provided to heat the material carried by the conveyor. For this purpose any suitable heating system may be employed. For example, hot air may be circulated from a furnace (not shown) through a duct 50, the heated air being forced through the mat on the conveyor and out of the oven through duct 52.

In the operation of the above-described apparatus, the condensed mat, treated as previously mentioned, is fed forwardly, initially at an accelerated speed, between conveyors 28 and 30 until its forward edge protrudes beyond the conveyors. The mat 18, when placed on the feed conveyors, is positioned so that the filaments lie generally transversely of the conveyors, the feeding operation moving the mat in the direction indicated by the arrows in Fig. 6. The protruding forward edge of the mat is grasped, suitably by hand, and drawn or expanded into an elongated web which is passed over table 34 and roll 38 and under roll 40, and carried onto conveyor 44 where the end of the web is temporarily secured in any suitable manner, for example, by weighting it. Feed conveyors 30 and 28 are then driven to constantly feed the mat forwardly, and conveyor 44 is driven at a much higher speed to continuously draw or expand the mat as it is supplied by the feed conveyors. Table 34 is positioned so that a portion of the flat plate presses against the under surface of the web. Roll 38 is similarly positioned so that the web is in contact with its upper peripheral portion and roll 40 is positioned so that the web is in contact with its lower peripheral portion.

As mentioned above, conveyor 44 is driven at a much higher speed than feed conveyors 28 and 30, the speed differential being such as to stretch the mat to, say, between 60 and 70 times its original length. During the stretching operation the filaments of the several layers shift or slide from directions substantially transverse of the mat or web, to positions, say, at a 45° angle or greater to the transverse dimension of the web to lie in what is here termed a direction "generally longitudinal" of the web. The shifting of the fibers is accompanied by a narrowing of the web as illustrated in Fig. 7. Roll 38 is positively driven in the direction indicated by the arrow at a speed preferably slightly greater than the speed of the oven conveyor, and roll 40 is driven at a speed greater than the speed of the oven conveyor and of roll 38. For example, if the oven conveyor is traveling at a speed of, say, 6' per minute, the surfaces of rolls 38 and 40 may rotate at a speed of, say, 6.3' and 6.6' per minute, respectively. The continued pull on the web, together with the action of fast driven roll 40, tensions the web to such an extent that, as it reaches the relatively slower moving oven conveyor, the upper and adjacent layers separate, although tied together by numerous intercrossing or interlocking filaments, and form into a series of longitudinally extending, substantially parallel corrugations which move into close, laterally adjacent relationship. Due to the drag of plate 34 and the slower speed of roll 38, the lower surface of the web is not tensioned to the same extent, or the tension is temporarily relieved and, although some corrugating and separation of the layers may take place, depending upon the particular operating conditions, the layers adjacent this surface will be relatively smooth and close together. The intermediate layers of the web will vary between the condition of the upper layers and the condition of the lower layers to form a portion of intermediate density and openness of structure. As the expanded or puffed web is carried through oven 42, the temperature is maintained in the oven by the circulation of heated air or otherwise, to the degree required to set and harden the binder to bond the filaments together into a unitary product.

The extent to which the original mat must be expanded or stretched to produce the desired effect will vary, depending upon the weight, filament diameter and character of the original mat.

Where a mat as disclosed in Fig. 2 is desired, the operations are identical except that the oven (see particularly Fig. 8) is provided with a pressure conveyor 54 overlying the upper reach of conveyor 44. Pressure conveyor 54 is made adjustable relatively to conveyor 44 by any suitable means (not shown) and is driven at the same speed as the latter. Conveyor 54 is similarly of open, wire mesh construction to permit the passage of the heated air therethrough. As the puffed mat passes between the two conveyors it is compressed to the desired thickness and density and is maintained in its compressed state during the binder setting operation, whereby it will retain its compressed condition after leaving the oven.

The products made by the instant invention are very resilient and compressible and, due to the gradation of structure from one surface to the other, perform admirably as filtering media. The process is relatively simple and does not require involved equipment.

Having thus described my invention in rather full detail, it will be understood that these details need not be strictly adhered to and that various changes and modifications may suggest themselves to one skilled in the art, all falling within the scope of the invention as defined by the subjoined claims.

What I claim is:

1. A product comprising a multilayer body of intercrossed filaments, the layers adjacent one face having a continuous succession of adjacent substantially parallel undulations extending at angles to the length of the filaments, and forming an openwork structure, and succeeding layers having similar undulations of diminished depth.

2. A product comprising a unitary multilayer body of intercrossed filaments, the layers adjacent one face having a continuous succession of adjacent substantially parallel undulations extending at angles to the length of the filaments, and forming an openwork structure, and succeeding layers having similar undulations of diminished depth, and a set binder bonding the filaments into the unitary body.

3. A product comprising a multilayer body of intercrossed, glass filaments, said body being expanded in the direction of its thickness to provide a relatively lightweight, open, porous structure and to provide the layers adjacent one face with a continuous succession of adjacent substantially parallel undulations extending at angles to the lengths of the filaments and to provide succeeding layers with similar undulations of diminished depth.

4. A product comprising a multilayer body of intercrossed, glass filaments, said body being expanded in the direction of its thickness and the layers adjacent one face thereof having a continuous succession of adjacent substantially parallel, continuous undulations extending at angles to the lengths of the filaments whereby a relatively lightweight, open, porous structure is provided, and succeeding layers having similar undulations of diminished depth whereby said body is of greater density adjacent the face opposite to said one face.

5. A product comprising a multilayer, unitary body of intercrossed, glass filaments, said body being expanded in the direction of its thickness and said layers having a continuous succession of adjacent substantially parallel, continuous undulations extending at angles to the lengths of the filaments, said undulations being of less depth adjacent one surface of the body than the other, and said body being of greater density adjacent said one surface.

6. A product comprising a multilayer, unitary body of intercrossed, glass filaments, said body being expanded in the direction of its thickness and said layers having a continuous succession of adjacent substantially parallel, continuous undulations extending at angles to the lengths of the filaments, said undulations being of less depth adjacent one surface of the body than the other, said body being of greater density adjacent said one surface, and a hardened binder bonding the filaments into the unitary body.

7. A product comprising a compressed, unitary, multilayer body of intercrossed, glass filaments, said body being expanded in the direction of its thickness and said layers having a continuous succession of adjacent substantially parallel, continuous undulations extending at angles to the lengths of the filaments, said undulations being of less depth adjacent one surface of the body than the other, said body being of greater density adjacent said one surface, and a hardened binder bonding the filaments into the unitary body.

8. The method comprising drawing a multilayer mat, in which the filaments of adjacent layers cross each other at acute angles, in a direction at right angles to the general lay of the filaments until layers of the mat assume an undulatory form and the mat expands in the direction of its thickness, and retarding the drawing movement of the layers adjacent one face of the mat to cause the mat to have a greater density adjacent said one face than the other.

9. The method comprising drawing a multilayer mat, in which the filaments of adjacent layers cross each other at acute angles, in a direction at right angles to the general lay of the filaments until layers of the mat assume an undulatory form and the mat expands in the direction of its thickness, and retarding the movement of the layers adjacent one face of the mat to cause relatively minor undulation of the layers adjacent said one face of said mat and relatively major undulation adjacent the opposite face.

10. The method comprising drawing a multi-

layer mat, in which the filaments of adjacent layers cross each other at acute angles and which contains an unset binder, in a direction at right angles to the general lay of the filaments until layers of the mat assume an undulatory form and the mat expands in the direction of its thickness, retarding the drawing movement of the layers adjacent one face of the mat while accelerating the drawing movement of the layers adjacent the other face to cause relatively minor undulation of the layers adjacent said one face of the mat and relatively major undulation adjacent the opposite face, and setting the binder.

11. The method comprising drawing a multilayer glass mat in which the filaments of adjacent layers cross each other at acute angles in a direction at right angles to the general lay of the filaments until layers of the mat assume an undulatory form and the mat expands in the direction of its thickness and during said drawing and expanding operation contacting one face of the mat with a relatively slower moving surface and the other face thereof with a relatively rapidly moving surface to cause greater expansion of said mat adjacent one face than the other.

12. The method comprising drawing a multilayer glass mat in which the filaments of adjacent layers cross each other at acute angles in a direction at right angles to the general lay of the filaments until layers of the mat assume an undulatory form and the mat expands in the direction of its thickness and during said drawing and expanding operation contacting one face of the mat with a relatively slower moving surface and subsequently contacting the other face of the mat with a relatively rapidly moving surface and then conveying the expanded mat away from the expanding operation.

13. The method comprising feeding a multilayer mat in which the filaments of adjacent layers cross each other at acute angles, drawing the mat in a direction at right angles to the general lay of the filaments until layers of the mat assume an undulatory form and the mat expands in the direction of its thickness, by contacting the mat at a point remote from the feed by means moving at a relatively high speed, contacting one face of the mat intermediate said feed and means with a relatively slow moving surface and contacting the other face of the mat intermediate said feed and means with a relatively rapidly moving surface to cause greater expansion of said mat adjacent one face than the other.

14. The method comprising drawing a multilayer glass mat containing an unset binder, and in which the filaments of adjacent layers cross each other at acute angles, until layers of the mat assume an undulatory form and the mat expands in the direction of its thickness, and during said drawing and expanding operation contacting one face of the mat with a relatively slower moving surface and the other face thereof with a relatively rapidly moving surface to cause greater expansion of said mat adjacent one face than the other, and setting the binder.

15. The method comprising drawing a multilayer glass mat containing an unset binder, and in which the filaments of adjacent layers cross each other at acute angles, until layers of the mat assume an undulatory form and the mat expands in the direction of its thickness and during said drawing and expanding operation contacting one face of the mat with a relatively slower moving surface and the other face thereof with a relatively rapidly moving surface to cause

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greater expansion of said mat adjacent one face than the other, compressing the mat and setting the binder.

16. The method comprising feeding a multilayer mat in which the filaments of adjacent layers cross each other at acute angles, expanding the mat in a direction at right angles to the general lay of the filaments until layers of the mat assume an undulatory form and the mat expands in the direction of its thickness and during said expanding operation drawing one face of the mat over a stationary plate, contacting said face of the mat with a relatively slowly moving surface, and contacting the other face of the mat with a relatively rapidly moving surface, to cause greater expansion of said mat adjacent one face than the other.

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