

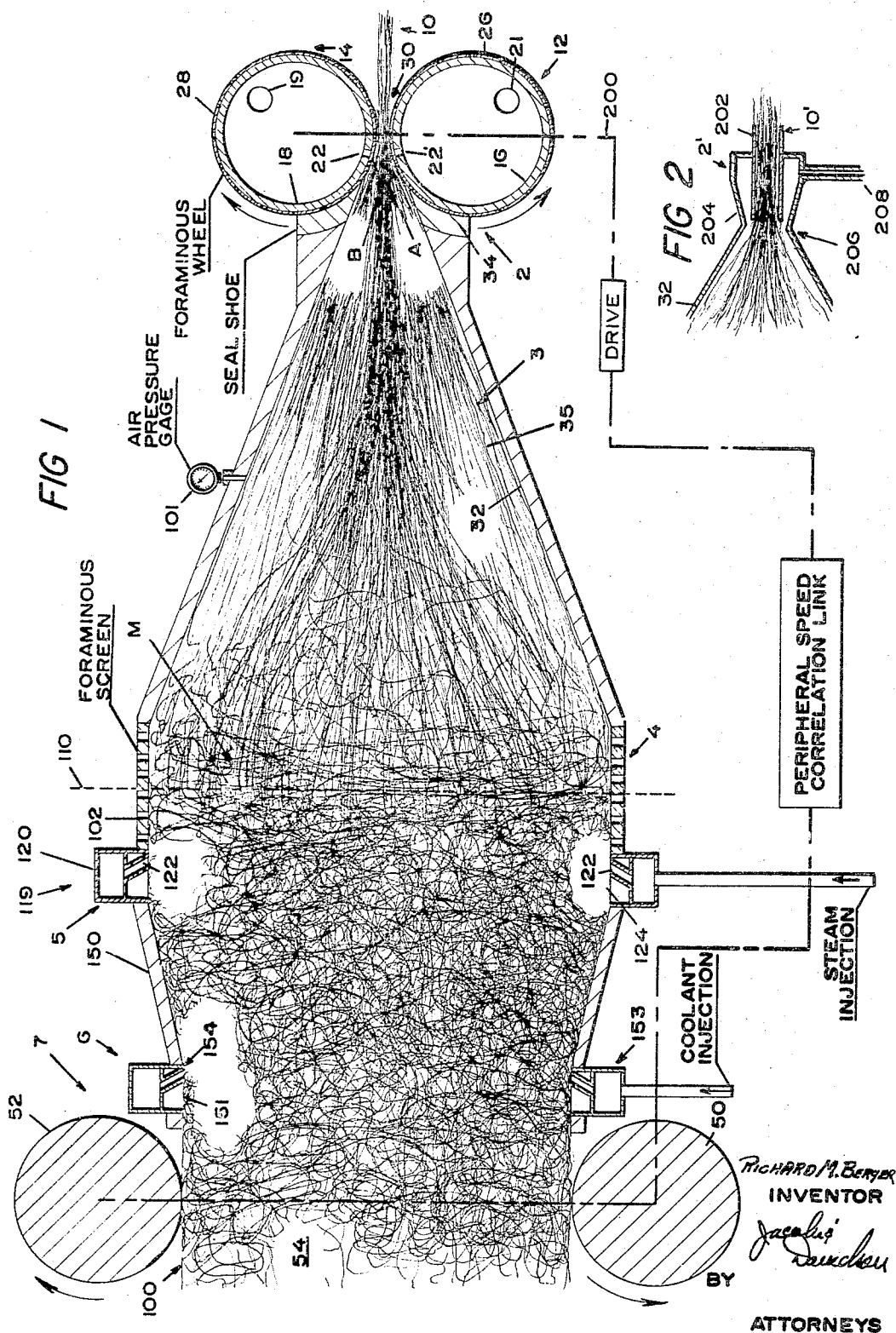
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METHOD FOR MAKING FIBROUS BODIES

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METHOD FOR MAKING FIBROUS BODIES

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10 Claims. (Cl. 156-180)

This application is a continuation of application Ser. No. 285,293, filed June 4, 1963, now abandoned.

This invention relates to bodies formed of what can be deemed "pneumatically woven" fibers, filaments, particles, and the like. Generally, the filaments or fibers are heterogeneously disposed in the ultimate product, although the heterogeneity during formation of the product can assume laminar aspects. The invention finds particular utility in the manufacture of wicks, although the various phases of the invention are applicable to a multitude of other products.

Wicks of the type in widespread use today conventionally comprise felt and/or cotton bodies. While such wicks perform satisfactorily under certain conditions, they are subject to "linting," and even further, fluid transmission therethrough and/or absorption thereby are not always acceptable, particularly where the wicks are used in special applications.

Thus, it has previously been suggested that wicks be made from synthetic filamentary material, and in fact, in certain of my prior co-pending applications, there are disclosed methods of making fibrous bodies which possess certain desirable wick-type properties. The prior applications referred to are as follows: Ser. No. 16,683, filed Mar. 22, 1960, now abandoned, Ser. No. 56,189, filed Sept. 15, 1960, and issued as U.S. Patent No. 3,095,343.

The application Ser. No. 285,293 is a continuation-in-part of each of these listed prior applications.

Consistent with the above-listed applications and the use of the methods thereof to make various forms of fibrous bodies including, for example, filter elements, liquid dispensers and applicators, and wick-type elements, continuous filaments, which have been gathered into a rope-like structure or so-called "tow" are generally treated initially by banding, stretching, plasticizer impregnation and/or other preliminary operations conventional in the cigarette filter art, and then treated to form the filaments in a rod-like shape. The fibrous elements in such a body are oriented primarily in a longitudinal direction although there are certain crimps and the like therein. Transversely projecting filaments or fibers which extend from the predominantly longitudinal base filaments provide restrictive passages within the body, and plasticizers or bonding agents are used to maintain the longitudinally disposed filaments in generally fixed relative relation. These bodies, however, are generally of a size commensurate with the initial dimensions of the raw material or tow fed to the processing stations. Specifically, if a conventional tow is used, then the ultimate product normally has a transverse cross-sectional area which corresponds generally in magnitude, although not in shape, with the cross-sectional area of the initial tow. There is thus a limitation on the ultimate product imposed by the size of the starting tow or rope and there is also primarily a longitudinal disposition of the base filaments.

Furthermore, with certain prior techniques, once the fibrous body is formed into its ultimate shape, an overwrap must be provided thereon so as to have a formation which is dimensionally stable. This is an additional problem which is faced when the methods of my aforesaid prior applications are not employed.

The foregoing discussion is not intended to be an exhaustive explanation of all methods which have pre-

viously been suggested for utilizing fibers to form an ultimately stable product. Instead, the foregoing discussion is presented to give an exemplary background and to generally explain certain problems and limitations which have previously been imposed on fibrous products made from so-called "filamentary tows."

The present invention is directed to the provision of novel fibrous products which are not subject to the limitations discussed above, and which can possess a comparatively high stiffness and resiliency for relatively low density. It is a primary object of the invention to provide fibrous products which are not limited in any substantial respect by the dimension or form of the starting material, which also are otherwise not limited as to ultimate transverse dimensions, which possess good resiliency characteristics, which possess an unusual stiffness for a comparatively low density, and which can be formed with desirable fluid transmission properties to adapt the same for use as wicks.

In essence, it is an object of the present invention to provide a fibrous product which can be formed in various sizes and shapes, which possesses good dimensional stability, which offers good stiffness and resiliency for low density, and which does not require for manufacture complicated equipment such as associated with weaving and knitting techniques. It is particularly important to understand that the invention offers first the advantage of obtaining the improved, new and novel product in varying dimensions and shapes, and secondly the advantage of permitting density control in the product so that density gradients throughout the structure can be achieved.

While the product aspects of the present invention are of particular significance, the method aspects thereof are also important. Thus, from a basic point of view, it is a primary object of the present invention to provide what may be deemed a pneumatic weaving process adapted to form articles of various sizes and shapes and with some substantial thickness, all through the use of a comparatively simple apparatus and comparatively inexpensive fibrous base or raw materials.

A further object of the invention in this regard is to provide a continuous process of forming fibrous material easily and inexpensively into a body of virtually any desired shape, size or thickness by pneumatic techniques which interweave the material and stabilize the product by injection bonding operations so as to yield a low density, inexpensive product with dimensional stability and controllable resiliency, porosity, and density.

It should be here understood that while wicks can be made in accordance herewith, the invention is adaptable to the manufacture of widely differing products possessing largely varying properties, some or all of which may, or may not, particularly suit a given product for use as a wick. Thus, while the invention provides improved wicks, and methods of making the same, the invention, in proper perspective can be viewed as providing new fibrous products and methods of making the same. More specifically, the present invention is concerned with a pneumatically woven fibrous product having the fibers heterogeneously disposed therein and so bonded as to yield a stiffness, porosity, thickness, resiliency, and exposed surface easily controllable to adapt the ultimate product for various specific intended uses.

As will become readily apparent as the ensuing description proceeds, the product of the invention can be formed of particles, fibers of either natural or synthetic origin, continuous or non-continuous fibers, or multi-filaments, and combinations thereof. In a preferred embodiment, however, the base or raw material is in the form of a continuous filamentary tow. A continuous filamentary tow means a material such as that which results when

filaments spun from a plurality of spinnerets are brought together and combined, preferably with filaments from other spinnerets, to form a continuous body of fibers "randomly oriented primarily in a longitudinal direction." As used in this specification and the appended claims, the phrase "randomly oriented primarily in a longitudinal direction" is intended to describe the condition of a body of fibers which are as a whole longitudinally aligned, and which are, in the aggregate, in parallel orientation, but which have short portions running more or less at random in non-parallel diverging and converging directions.

Continuous filamentary tows of various materials, including cellulose acetate filaments, have heretofore been developed, and the cellulose acetate tows have commonly been used to adapt segments thereof for use of cigarette filters, cigar filters, and the like. Generally, the fibers of the tow are formed with spinneret devices, and the strands exiting from such spinneret devices, as suggested above, are bunched together to form a "raw tow" which is wound, or folded, into a bale for subsequent processing. The subsequent processing operations usually involve, in addition to unwinding of the raw tow, spreading apart of the fibers of the tow to provide a relatively thin fiber layer, tensioning of the fibers to eliminate the crimps therein, impregnating the fiber layer with a plasticizer which can bond adjacent fibers together, and gathering the "bonded" layer through a suitable funnel or the like to form a "treated" cylindrical tow having filaments therein which are primarily oriented in a longitudinal direction. Then, in many instances, the treated tow is wrapped in a suitable paper to form a stable rod. The paper-covered rod is then cut into small segments by an ordinary cigarette-cutting machine and "cured" or maintained in lengths and "cured."

Alternatively, in accordance with my above-listed applications, the so-called "treated" tow is subjected to a steam and/or steam and plasticizer injection operation and preferably an air injection operation so as to provide a dimensionally stable product of suitable porosity which requires no overwrap.

The above somewhat specific discussion of prior tow treating techniques is incorporated merely to explain the type of tow which can be used in accordance with the preferred embodiment hereof. It is to be clearly understood that the invention is not specifically limited to formation of products from tows, much less previously available tows, nor are filaments formed from spinnerets necessarily prerequisite starting material for the invention. Instead, as indicated above, various fibrous materials, filaments, and the like can be used as base materials, and the starting form thereof can be widely varied. At the same time, the use of filaments, and a tow containing the same, facilitates certain method steps hereof and since tows of spun filaments are readily available, or can be easily formed, at comparatively low cost, a filamentary tow provides a desirable base or starting element for use in accordance with the invention.

In previous processes of handling tows, as discussed immediately above, the ultimate product generally has the filaments thereof oriented primarily in a longitudinal direction—i.e., the filaments extend generally parallel to one another, and while adjacent filaments are bonded together, there is little interweaving of the filaments. With the present invention, however, the ultimate product has heterogeneously disposed filaments which are so oriented and disposed with respect to other filaments in the product, that all filaments are generally heterogeneously woven together without any predominate longitudinal orientation or longitudinal parallel relationship therebetween.

Another important differentiating consideration between prior products formed from tows and products formed from tows in accordance with the invention, involves the relative size of the product as related to the volume of filaments. Prior final products, as indicated above, gen-

erally have a size which conforms closely with the original size of the "raw tow" or in any event, whose transverse dimensions are not substantially different from those of the gathered raw tow. Consistent with a preferred aspect of the present invention, however, the volume of the ultimate product can differ radically from the volume of the initial "raw tow"—i.e., the absolute volume of the filaments as taken in transverse dimension. Thus, the present invention does not require a heavier tow to be fed, or a plurality of tows to be fed simultaneously, to an initial processing operation. Instead, a conventional tow can be used alone in the formation of products having substantially greater transverse dimensions than those of the starting tow.

While the relative transverse size of the tow to the final product is particularly significant, it should be understood that substantially increased density and compactness can be achieved easily in a final product manufactured in accordance herewith as compared with densities and compactness achievable with prior commercially practical techniques.

In the preceding discussion, as well as in the following description and claims, the terms "fibers" and "filaments" are used generally interchangeably. Thus, the term "filaments" includes synthetic filaments, for example, as well as staple fibers. Similarly, the term "fibers" includes, for example, both such base materials. With respect to the base materials, and regardless of the exact form thereof, cellulose acetate, viscose, polyethylene and polypropylene are particularly suitable and are easily usable, especially when in tow form.

Bearing in mind the foregoing discussion and basic considerations, the invention will be better understood by reference to the following detailed description of illustrative and preferred embodiments thereof. To facilitate the detailed explanation of the invention, as well as of the product formed in accordance with the methods thereof, attention is directed to the attached drawings, in which:

FIGURE 1 is a schematic illustration in longitudinal cross section of one form of apparatus processing a tow in accordance with the methods hereof; and,

FIGURE 2 is a fragmental schematic illustration in longitudinal cross section of a modified form of input station which is conveniently usable with the apparatus arrangement otherwise shown in FIGURE 1.

Before considering the drawings in detail, it should be understood that the starting material can take various forms and that the feed-in means or assembly can be varied. For example, the feed-in means can be a vacuum pump of conventional design, a rotary airlock feeder of conventional design, a screw conveyor of the type capable of providing a continuous feed without permitting significant gas escape from the apparatus, a venturi feed system, or a roll feed system. The two latter mentioned types of feed-in means are discussed in some detail below, and from such discussion, the use of the other types of feed-in means here listed will become apparent.

Referring now more specifically to the drawing, the apparatus schematically shown therein includes an input station 2, an expansion station 3, a gas escape station 4, a bonder injection station 5, a coolant injection station 6, and an output station 7. Entering the feed-in station 2, as shown, is a tow 10 which is formed of synthetic filaments such as cellulose acetate, or viscose, and which preferably has been previously stretched, banded, impregnated and the like, consistent with conventional prior art techniques discussed above and applicable to conventional tows used in the formation of cigarette filters. The tow 10 may be of any particular shape but generally has a rope-like configuration, and comprises a multiplicity of filaments which are primarily randomly oriented in a longitudinal direction. If desired, however, the tow can be initially spread before entering the input station 2 of the apparatus of FIGURE 1.

Regardless of the condition of the tow 10 as it enters

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the input station 2, it provides a volume of filaments as fibers, which are fed into the apparatus by means simultaneously advancing the tow and feeding therein a gaseous medium in the general direction in which the tow is advancing. Such means, as shown, includes a pair of cooperating roller structures 12 and 14, having a feeding nip 30 therebetween through which the tow advances.

Each of the roller structures 12 and 14 can well comprise a core member 16 and 18 respectively, which core member is impervious to gas on opposite sides of a longitudinally extending outlet passageway 22, 22' respectively. The core members 16 and 18 are preferably solid sleeves.

Disposed peripherally of core members 16 and 18 are foraminous sleeves 26 and 28 respectively which also form part of the respective roller structures 12 and 14. The foraminous sleeves 26 and 28 are supported to rotate about the core members 16 and 18. Since the sleeves 26 and 28 are foraminous, as the sleeves rotate about the core members, the apertures or perforations therein come successively into alignment with the longitudinally extending passageways 22 and 22' of each of the core members 16 and 18 respectively.

Consistent with the invention, air or other inert gas under pressure is fed interiorly of the core members 16 and 18, through air inlets 19 and 21. Accordingly, as the foraminous sleeves 26 and 28 rotate about the core members, air is ejected from each of the core members in the directions indicated by the arrows A and B respectively. Any suitable drive means can be used for drivingly rotating one, and preferably both of the sleeves 26 and 28, about respective core members 16 and 18. There is thus shown in the drawing only a schematic drive connection 19. Still in normal operation, the sleeves 26 and 28 rotate in opposite directions, whether only one, or both are driven.

As an alternative to the use of a roller feed-in arrangement, the tow can be fed interiorly, or centrally of an enclosed housing through an input tube, for example, and air fed therein about the tube so as to push the tow forwardly. Such an arrangement is shown in FIGURE 2. The feed-in station 2' in FIGURE 2 includes a feed tube 202 disposed centrally of a feed housing 204. The housing 204 forms a venturi throat as at 206, where it joins the housing 32 at expansion station 3. The tube 202 serves as an entrance for the tow 10 and with the feed of a gaseous medium, e.g., air, under pressure through the input coupling 208 of housing 204, the pressure variation created at the venturi throat serves to draw the tow 10 into the apparatus. This type of feed-in arrangement serves the same purpose as the feed-in arrangement shown in FIGURE 1 which will now be described in somewhat further detail.

Returning again to the operational steps of the invention, as related particularly to the arrangement shown in FIGURE 1, since the tow 10 passes over the foraminous peripherally disposed sleeves 26 and 28 of each of the roller structures, and since the sleeves are driven in opposite directions, the tow which passes through the nip 30 formed between the roller structures 12 and 14 is injected with inert gas preferably air, leaving the core members 16 and 18 and traveling through outlet passageways 22 and foraminous sleeves 26 and 28 in the directions A and B. This gas creates an expanding action on the individual filaments of the tow 10 after the same leave the nip 30. To control this expanding action, there is provided the expansion chamber or station 3, which includes a tapering housing extending between the input station 2 and the gas escape station 4. The input edges of the tube 32, i.e., the edges on the right end as to prevent undesired escape of the gases leaving the core member and so as to thereby maintain the pressure and confinement of gases entering the chamber or station 3. It is these gases, as indicated above, which cause a random expansion and separation of the individual filaments of the tow 10.

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With the arrangement of FIGURE 2, undesired escape of gases is prevented by feeding a sufficient quantity of material to the tube 202 and by forming the venturi throat to produce a feed which prevents any undesired escape of input pressures through the feed-in means.

Regardless of the particular type of feed-in arrangement which is employed, the invention provides for a control of the relative linear speed of the material at the input and output stations. In the following paragraphs, detailed reference is made to such speed control in particular relation to the arrangement of FIGURE 1. As specifically set forth, there is a mechanical adjustment of relative roller speeds. However, it will be readily apparent that the speed adjustment desired can be obtained with the arrangement of FIGURE 2. Specifically, in this instance, as opposed to having a mechanical relationship between roller speeds, one would establish a particular relationship between the speed of the output rollers, and the input speed of the material as determined by the pressure on the gas fed to the gas inlet 208, and the design of the venturi throat.

Bearing the above in mind, reference will now be made to the operation of the apparatus with reference to FIGURE 1, but with the understanding that the operation is basically the same, except as noted above, with the feed-in arrangement of FIGURE 2.

The filaments or fibers at the station 3, or traveling through the housing 32 are generally designated by the numeral 35, and it should be understood from the schematic showing that they are primarily separated into individual threads or yarns which collectively, and in generally spaced relation to one another, fill housing 32. It should also be understood that generally the same action is achieved whether the filaments are continuous or non-continuous throughout their length. The action within the chamber 3 is a separating action which in essence serves to suspend the filaments in the air stream or gas stream created by the gas leaving the core members 16 and 18.

In order to understand the manner in which the filaments are arranged and controlled between the output end of expansion chamber 3 and the output station 7, it is helpful to review the operation in somewhat reverse sequence.

Consider initially the output station 7 which, as shown, includes a pair of cooperating aligned rollers 50 and 52 having a nip 54 therebetween which is substantially wider than the nip 30 between the input roller structures 12 and 14. The rollers 50 and 52 are rotated in synchronism with the foraminous sleeves 26 and 28, through a drive control schematically shown in the drawing and designated by numeral 200. However, the rollers 50 and 52 are driven at a substantially reduced linear peripheral speed with respect to the peripheral speed of the sleeve members 26 and 28. In other words, the input speed of the tow, or linear input speed of the filaments is substantially greater than the linear output speed of the formed product 100 leaving the nip between rollers 50 and 52. Thus, as should be apparent, there is a retardation or "back-up" between the output station 7 and the output end of the expansion chamber 3. This retardation would be the same, as indicated above, with the arrangement of FIGURE 2, but instead of the drive control 200, the operator would adjust the feed-in pressure to inlet 208 such that the speed of the incoming material through tube 202 was less than the speed of the material past the rollers 50 and 52. Alternatively, the speed of the rollers 50 and 52 would be adjusted relative to the input pressure. In either instance, as well as with the arrangement of FIGURE 1, the nip between rollers 50 and 52 is effectively an extrusion orifice since the material leaving the apparatus is generally an extruded product.

Now, consider the escape station 4 where a foraminous screen member 102 is provided. This screen member is disposed contiguously and in longitudinal alignment with

the end of the expansion housing 32 wherein the fibers or filaments are gradually expanded as shown. The screen 102 permits gas escape from the apparatus, but regardless of the gas escape through the screen member at station 4, there inherently must be some "back-up" between expansion station 3 and output station 7 due to the speed differential between input and output, as discussed above.

In brief, the operating conditions at the stations 4, 5 and 6 result in the formation and curing of the ultimate product. Specifically, these operating conditions can be summarized as follows: the foraminous screen member 102 permits escape of air and moisture which creates turbulence in the space just beyond the screen member, thus creating a condition in which the fiber or filament mass becomes its own moving screen. In the confined and dimensioning space 150, the flow of steam through ports 122 and the flow of coolant through ports 153 result in a steam current and a coolant current which "buck" each other and instantaneously fix the fibers or filaments in a curled, turbulent permanent condition. This action permits a wide control of product density and dimensions. In essence, the mass of fiber or filaments becomes its own screen and filter for the steam and coolant.

Further explaining the operation summarized in the preceding paragraph, it is helpful to consider an example. For this example, assume temporarily that due to the material "back-up," a wall type surface appears at the plane 110 shown in dotted lines. With the appearance of such surface, fibers or filaments traveling to the station 4 are caused to bend in a generally laminar but otherwise heterogeneous manner as they move toward the wall. As the fibers or filaments 35 traveling from expansion housing 32 move forward toward the wall layer, they are pushed against such layer in a laminar but heterogeneous manner with the gas traveling through such housing causing the disposition and abutment of the fibers against the wall layer, and with the gas then escaping through the foraminous screen 102. When the apparatus is in operation and there is a sufficient build-up of the fibers, then successive wall layers advance forwardly and there is essentially established a rear face in the area of station 4 which rear face comprises successive new layers of heterogeneously deposited filament portions that serve as the surface against which further fibers or filaments are deposited. In other words, if a wall were initially inserted at the axis 110, and then with the build-up, if the wall was moved toward the output station 7 until the material build-up existed between the rollers 50 and 52, thereafter there continuously would be a wall in plane 110 formed of advancing filament layers. In practice, and once the operation is started, any particular deposited layer of fibers moves toward the output station 7, but there are continuously wall surfaces which, while being composed of different layers of fibers, essentially present a wall surface remaining at the station 4.

By virtue of the expansion and separation of the filaments in expansion chamber 3, by virtue of the dimensions of foraminous screen 4, and further, by virtue of the difference between the input and output speeds, the filaments in the original tow are formed, in accordance with the above described technique, into a mass that has a substantially larger transverse dimension than the initial tow used as a base for forming the mass.

Moreover, and equally important, the fibers are pneumatically arranged heterogeneously, and without any prescribed or predetermined longitudinal orientation. In fact, as presently understood, the fibers in the formed mass, generally designated as M, extend in a plurality of directions generally transverse to the direction thereof as fed through the input nip 30. The fibers or filaments are, in essence, heterogeneously deposited in adjacent and overlapping relation to one another in generally successive layers extending transverse to the direction of travel thereof. Additionally, the above-described operations

provide automatically, an at least substantially uniform filament disposition throughout the formed mass where-by there is substantially uniform filament quantity and similar heterogeneity in any cross-section of the formed mass. This automatic uniformity apparently results from the turbulence of the inert gases leaving expansion housing 32 at station 4, as well as from other gas currents referred to below.

From the preceding description, it should be apparent, that as the final product is being formed, i.e., as layer after layer of fibers are heterogeneously placed against the rear of a formed body as it advances, confinement of the fibers and the pneumatic action of the gases leaving the input station serve to maintain the fibers in a generally dimensionally stable confined mass. While the fibers, as confined, are pneumatically held in the stable position, the invention provides for bonding and setting of the fibers. To this end, a bonding injection is carried out at the station 5, and a setting injection is carried out at the station 6.

It is difficult, and possibly inaccurate, to definitively separate the action which occurs at the stations 4, 5 and 6. In the sense of location, the station 4 is an escape station, the station 5 is a steam injection station preferably, and the station 6 is a coolant injection station. At the same time, as indicated above, there is a somewhat combined action in the location of all of these stations. The exact gas flow between the station 6 and the station 5, and in turn the exact gas flow between the station 5 and the station 4 is not precisely ascertainable.

However, as presently understood, it appears that the steam and air, preferably used respectively for bonding and setting, create a turbulent atmosphere while acting cumulatively to bond and set the accumulated mass generally instantaneously. A suitable product for certain purposes can be produced without the coolant injection station, but for the most desirable ultimate product, the coolant injection station is not only significant, but important.

Bearing in mind the generally cumulative action referred to in the preceding paragraphs, attention can be directed separately to the individual stations 5 and 6, as if the action at each station was independent. In other words, the stations 5 and 6 are separately discussed below subject to the understanding that the action at each station, in fact, appears to be cumulatively combined with the action at the other station.

At the bonding injection station 5, there is provided an injection die 119 including a peripheral chamber 120 having a plurality of passageways 122 extending therefrom and entering the inner surface 124 thereof, preferably adjacent the juxtaposed edge of the foraminous screen 102. The particular bonding medium injected at the station 5 will depend upon the particular raw material included in the tow 10. If thermo-plastic synthetic fibers are used, for example, then the injection carried out at station 5 can well comprise a steam injection, wherein the steam carries plasticizer particles or particles of a bonding agent therein. The plasticizer or bonding agent in this instance, would, of course, be compatible with the fiber materials for bonding thereof.

If the synthetic fibers are thermo-plastic, then the heating action of the steam would serve to soften certain of the filaments, or the surfaces thereof, causing the same to become adherently tacky for bonding with adjacent filaments. In addition, the steam can simultaneously serve to deliver the plasticizer or bonding agent particles to the filaments themselves for additional bonding there-between if such bonding is desired.

The particular shape of the foraminous member 102, of the interior surface 124 of the die 119 at the bonding injecting station 5, and of the outlet tube or passageway 150 which is provided to connect the station 5 with the station 6, predetermines the particular shape

and size of the particular product to be formed. Similarly, the interior surface 151 of the die 153 at the coolant injection station 6 would be shaped to conform with the particular product being made.

In any event, once the shape has been pre-selected, and operation has started, a heated gas having vapor particles therein is passed onto the formed body entering the station 5, and this is immediately after or simultaneously with the gathering of such body into the mass M. Preferably, as indicated, steam is used for the first injection treatment, and such steam is passed under pressure into the confined area defined by the foraminous screen and inner surface 124 of die 119, and at an angle with respect to the longitudinal axis of the mass whereby the steam travels countercurrent to the direction of movement of the formed body. Although it has been found that a substantial increase in bonding of the formed body can be achieved by merely subjecting the same to steam alone, and/or steam having plasticizer particles therein, immediately after the formation thereof, and while the same is confined, it has also been found that more uniform bonding of the fibers and greater dimensional stability of the body can be obtained when the steam is directed onto the body countercurrent to the direction of movement thereof, and at an approximately 45° angle with respect to the longitudinal axis of the body whereby the steam passes through the body and out of the body through the foraminous member 102.

The pressure at which the steam is introduced at the bonding station 5, or the pressure at which other vaporized gas carrying bonding particles therein is introduced at this station can be varied, but the pressure, in accordance with the preferred embodiment, serves to cooperate with the body whereby to retard movement thereof toward the output station 7. The retardation results from the angular injection of the vaporized gas at the station 5. Moreover, the angular injection directs the vaporized gas and bonding particles carried therein toward or into the area where the filaments 35 are being heterogeneously deposited against the advancing then rear surface of the mass M. Due to the use of a vaporized gas for carrying the bonding medium, and the injection thereof as aforesaid, there is generally a uniform distribution of the bonding particles throughout the formed body.

If the station 5 was provided without the station 6, the formed mass would have some dimensional stability or resistance to deformation. However, the preferred embodiment hereof, as indicated above, contemplates a further treatment of the mass, which further treatment, while described separately, is combined with the treatment at the station 5 in effect.

The material passes through the confined space 150, where the bonding agent sets or is cured instantaneously. In the embodiment shown, the confined space or tube 150 is tapered slightly inwardly so as to exert a very small compression on the mass thereby causing possibly a more uniform bonding of the interior filaments as well as a comparatively smooth outer surface on the formed body. However, the tapering is not required, and a straight-through passage is completely satisfactory and can be preferred in some instances. Regardless of the shape of space 150, the advancing formed mass travels therethrough and to the station 6 where a coolant, preferably air, is injected into the formed mass. At the station 6, there is provided a die like the die provided at the station 5. However, a coolant is injected into the tow through the passageways 154 of this die which are also preferably disposed angularly with respect to the formed mass at an angle of approximately 45° with respect to the longitudinal axis of the advancing mass. The coolant is injected counter-current to the direction of travel of the formed body, just as the vaporized gas is so injected at the station 5. Here again, injection of the

coolant serves to retard advancing movement of the formed mass thereby providing additional control on the forward speed thereof. Still further, by injecting the coolant at the station 6, there is a generally uniform porosity of the body maintained together with a complete curing thereby providing a completely dimensionally stable formed article leaving the station 6. In essence, the formed body has its filaments bonded and successively cured in sequential steps and at substantially the same rate. Thus, production of a formed dimensionally stable body is easily achieved at a reasonable production rate.

The formed body, as it leaves the station 6, is essentially an extruded body. It passes between the output station rollers 50 and 52, or through the nip 54 thereof, and as explained more fully above, the speed of these rollers is controlled relative to the speed of the input rollers.

Now, at this point, it is desirable to review the control of the advancing movement of the formed body. The input foraminous sleeves 26 and 28 are driven at a first predetermined speed. The linear surface speed of these rollers is accordingly also predetermined, and this linear surface speed is substantially less than the linear speed of the formed body past the stations 5 and 6. Moreover, the linear surface speed at the output station rollers 50 and 52 is substantially less than the linear surface speed of the input foraminous sleeves 26 and 28.

The change in linear speed of the filaments as they advance through the apparatus of FIGURE 1 results from not only the relative speed of the input rollers and output rollers, but from the control over the advancing speed of the formed mass exercised by the countercurrent bonding injection at station 5 and coolant injection at station 6. Thus, in the final analysis, a correlation between the injection retarding effects and the relative speeds of the input and output rollers is maintained so that the product possesses the desired density characteristics.

Having now described in some detail each of the processing operations performed in accordance with the preferred embodiments hereof, and having also explained generally an apparatus which can be used for performing the method hereof, attention can now be directed to certain more basic considerations of the invention, both from the product standpoint, and from the method standpoint.

With particular regard initially to the method, it should be apparent that the apparatus shown in the attached drawing can properly be regarded as providing a confined area between the input end thereof existent at the nip 30, and the output end thereof, as existent adjacent the output rollers 50 and 52. Viewed in this respect, the basic method steps hereof contemplate continuously passing fibers at a predetermined average linear speed into such confined area through the input end thereof, and continually removing fibers as processed from such area through the output end thereof at a linear speed less than the input speed. Following the introduction of the fibers within the confined area, the volume thereof is expanded by passing gas therethrough and permitting the volume to expand, then, the gas is permitted to escape from the confined area following the expansion to thereby permit the fibers to heterogeneously gather in a confined mass within the confined area. Finally, the fibers or filaments in the confined mass are bonded to adjacent fibers therein to form a dimensionally stable mass.

As an alternate approach to definition of the basic method aspects hereof, the apparatus can be viewed as providing first, second and third contiguous confined areas, the first confined area being the expansion chamber 3, the second confined area being that bounded by the foraminous screen 102, and the third confined area being that provided at, and between, the respective bond-

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ing and coolant injection stations. Consistent with this approach, the fibers or filaments are separated in the first confined area by continuously feeding the same thereto together with gas under pressure. Then the filaments or fibers are continuously passed into the second confined area and the gas is permitted to escape from such area. Moreover, within the second confined area, the fibers or filaments are heterogeneously deposited in adjacent and overlapping relation to one another in generally successive layers extending transverse to the direction of travel of the filaments within the apparatus. The generally successive layers are continuously passed into the third confined area, and a gas having a bonding vapor therein is injected onto the layers whereby the gas passes through the layers and the vapor bonds the filaments together. The layers are continuously removed from the third confined area at an average linear speed less than the average predetermined input linear speed.

Either of the above approaches to definition of the process hereof summarizes basic operations involved therein, and indicates the non-criticality of the particular apparatus employed. The first approach, however, is preferred because it is more basic and more generally definitive than the second approach, at least in certain respects.

Regardless of how the method is definitively approached, by practicing the same, there results a new product. This product, as formed, is elongate in that it is generally extruded. The product is a fibrous body comprising a multitude of filaments and preferably a bonding agent for the filaments. At least a substantial portion of the filaments have a length exceeding at least the smallest transverse dimension of the body, and the filaments forming the substantial portion are heterogeneously bent and arranged in the body with major portions thereof extending in directions transverse to the longitudinal axis of the body or generally parallel to the smallest transverse dimension thereof. This disposition of the fibers results from the heterogeneous deposit thereof in the manner described above—i.e., against the rear surface of the formed mass formed by successively advancing layers. The bonding agent within the body joins adjacent fibers together in spaced locations within the body and fixes the filaments in relation to one another. Of course, the body as formed can be cut into suitable lengths, as desired, for particular use of segments thereof as wicks, for example.

As should be apparent, when a tow is used, as described above, and as the only basic or initial starting material, then generally all of the fibers or filaments within the formed body have a length exceeding the shortest transverse dimension of the ultimate article. However, it should also be apparent that it is not necessary to use a tow and/or to use continuous filaments such as existent within a tow. Instead, other forms of filamentary or fibrous material can be used, and moreover, even when a tow is used as a basic raw material, particles, multi-filaments, and /or other materials of varying particle size and individual length, can be mixed with the tow as introduced into the apparatus so as to form an ultimate product consistent with the above description thereof, but having diverse-type constituent elements suitable for a particular purpose.

Although the invention has been described hereinabove in considerable detail, and although it has been explained that various filaments including cellulose acetate and viscose filaments can be used, for particular examples of cellulose acetate tows which are suitable for use in accordance with the invention, for particular details as to types of plasticizers which can be used therewith, and for particular details as to injection pressures suitable therefor, attention is directed to my aforesaid prior co-pending application Ser. No. 56,183. Generally, the operating conditions set forth in such prior application are here applicable, insofar as pertinent to the steps performed in accordance herewith. One additional factor,

however, deserving of consideration regards the relative range in difference between the respective input and output speeds. It has been found that completely satisfactory results can be obtained when the ratio of input speed to output speed is maintained within a range of between 1:1 and 100:1.

After reading the foregoing detailed description of illustrative and preferred embodiments hereof, it should be apparent that the objects set forth at the outset of this specification have been successfully achieved. Accordingly, what I claim is:

1. In a method of making a dimensionally stable article from a body of thermoplastic filaments, the steps of:
 - (a) continuously passing said filaments at a predetermined first average linear speed into a first confined area having at least a portion thereof expanding in the direction of travel of said body;
 - (b) continuously feeding gas under pressure into said first confined area to separate said filaments;
 - (c) continuously passing said filaments into a second confined area contiguous with said first confined area;
 - (d) heterogeneously depositing said filaments in said second confined area in adjacent and overlapping relation to one another in generally successive layers extending transverse to the direction of travel of said filaments;
 - (e) continuously permitting said gas under pressure to escape from said second confined area;
 - (f) continuously passing said generally successive layers into a third confined area contiguous to said second confined area, and injecting hot vaporized liquid therein onto said layers whereby said vaporized liquid passes through said layers and to bond said filaments and layers together as a stable article; and,
 - (g) continuously removing said layers from said third confined area at a second average linear speed less than said first predetermined average linear speed.
2. In a method of making a dimensionally stable article, the steps defined in claim 1, wherein step (f) further includes injecting a coolant gas stream onto said layers following the injection therein of said vaporized liquid.
3. In a method of making a dimensionally stable article, the steps defined in claim 2, wherein said vaporized liquid has plasticizer particles therein, and wherein said filaments are synthetic filaments.
4. In a method of making a dimensionally stable article, the steps defined in claim 1 wherein the injecting of step (f) is carried out by delivering steam under pressure to the periphery of said layers.
5. In a method of making a dimensionally stable article the steps defined in claim 1 wherein said body of filaments comprises a tow.
6. In a method of making a dimensionally stable article, the steps defined in claim 5, wherein said layers have a cross-sectional area transverse to the direction of travel thereof through said confined areas which substantially exceeds the cross-sectional area of said tow, transverse to the direction of travel thereof into said first confined area.
7. In a method of making a dimensionally stable article, the steps defined in claim 1 wherein steps (a) and (b) are carried out simultaneously.
8. In a method of making a dimensionally stable article from a body of thermoplastic fibers, in a confined area having an input end and an output end, the steps of:
 - (a) continuously passing fibers at a first average linear speed and in a given general direction into said confined area through said input end thereof;
 - (b) continuously removing fibers as processed in accordance with following steps (c) and (d) from said area through said output end at a second average

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age linear speed less than said first average linear speed;

- (c) following step (a), and within said area, reorienting the fibers passed through said input end and heterogeneously gathering said fibers in adjacent and overlapping relation to one another in generally successive layers extending transverse to the direction of travel of said fibers, by passing gas into said area and permitting the same to escape therefrom; and
 (d) following step (c), passing hot vaporized liquid into said heterogeneously gathered fibers to bond the fibers and layers together and then cooling the

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bonded fibers and layers to form a dimensionally stable mass therefrom.

9. In a method of making a dimensionally stable article, the steps defined in claim 8 wherein said thermoplastic fibers are plasticized.

10. In a method of making a dimensional stable article, the steps defined in claim 8 wherein said vaporized liquid has a bonding vapor therein.

No references cited.

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