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Walton et al.

[11] **3,810,280**

[45] **May 14, 1974**

[54] **METHOD AND APPARATUS FOR LONGITUDINAL COMPRESSIVE TREATMENT OF FLEXIBLE MATERIAL**

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[73] Assignee: **said Walton, by said Munchbach**

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[52] **U.S. Cl.** **26/18.6,** 264/282

[51] **Int. Cl.** **D06c 21/00**

[58] **Field of Search** 26/18.6; 264/282

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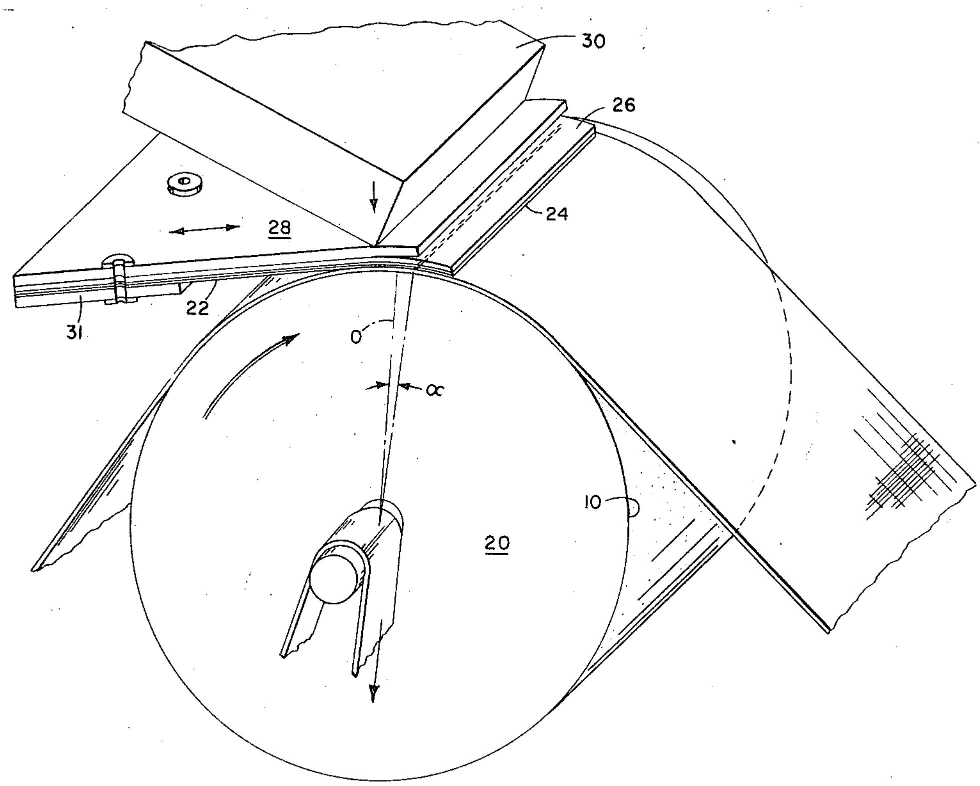
Primary Examiner—Robert R. Mackey
Attorney, Agent, or Firm—William R. Hulbert

[57] **ABSTRACT**

Longitudinal compressive treatments for producing a wide variety of effects in travelling lengths of sheet materials such as textile fabrics, yarns, paper, film, foil and other webs by confining the material against a drive surface by means of a confining surface and driving the material into engagement with a retarder located beyond the trailing edge of the confining surface and also in spaced relation to the drive surface. The retarding surface is provided by material which is essentially inextensible in the machine direction and is provided with a multiplicity of portions which grip and release the passing material. The confining surface is at least in part spaced closer to the drive surface than is the retarder. The forwardly driven material impinges against a column of already compressed material under the trailing portion of the confining surface and under the retarder. The drive surface propels the continuously formed column from beneath the surfaces.

25 Claims, 24 Drawing Figures



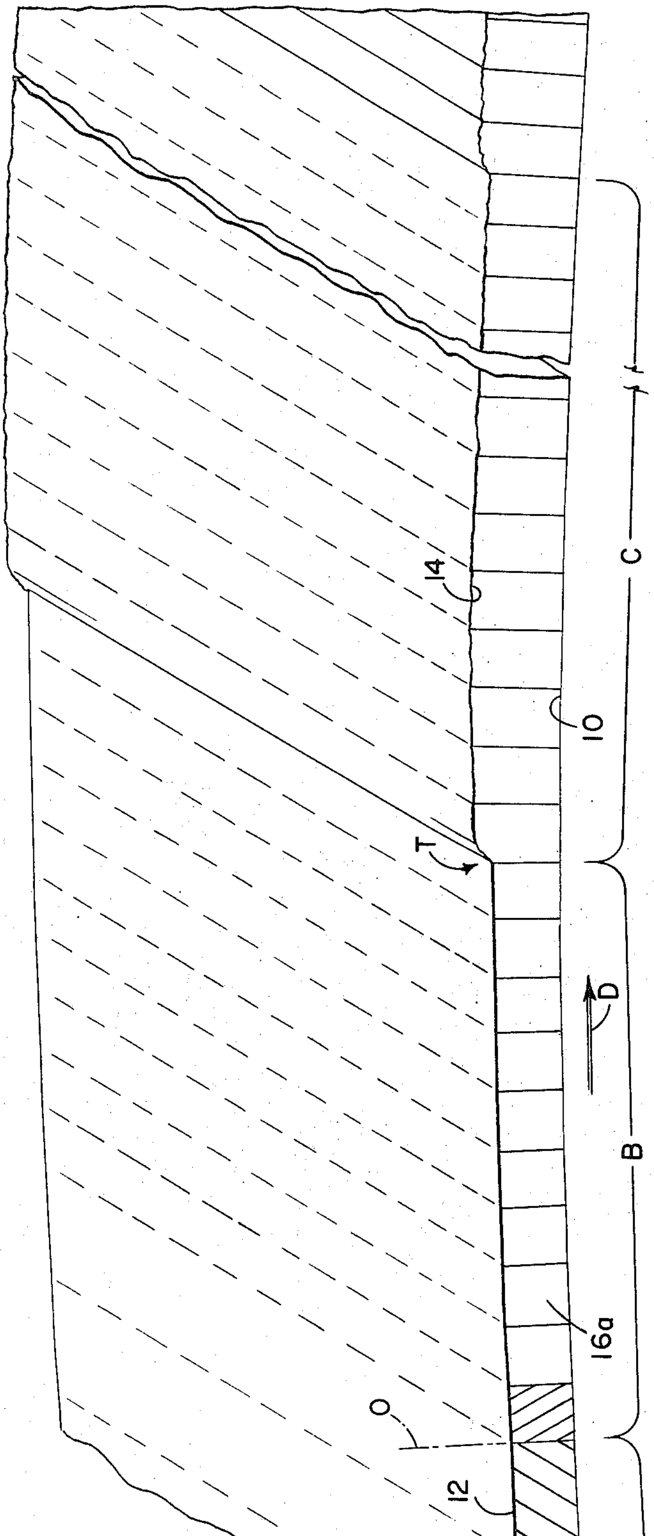


FIG 1

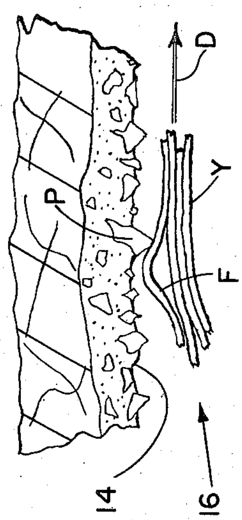


FIG 2

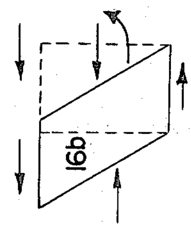


FIG 3a

FIG 4

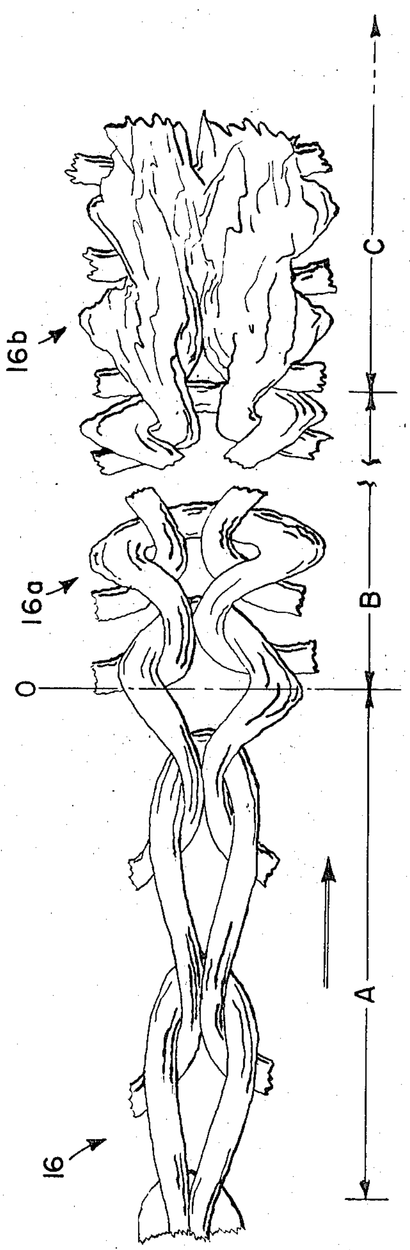


FIG 3

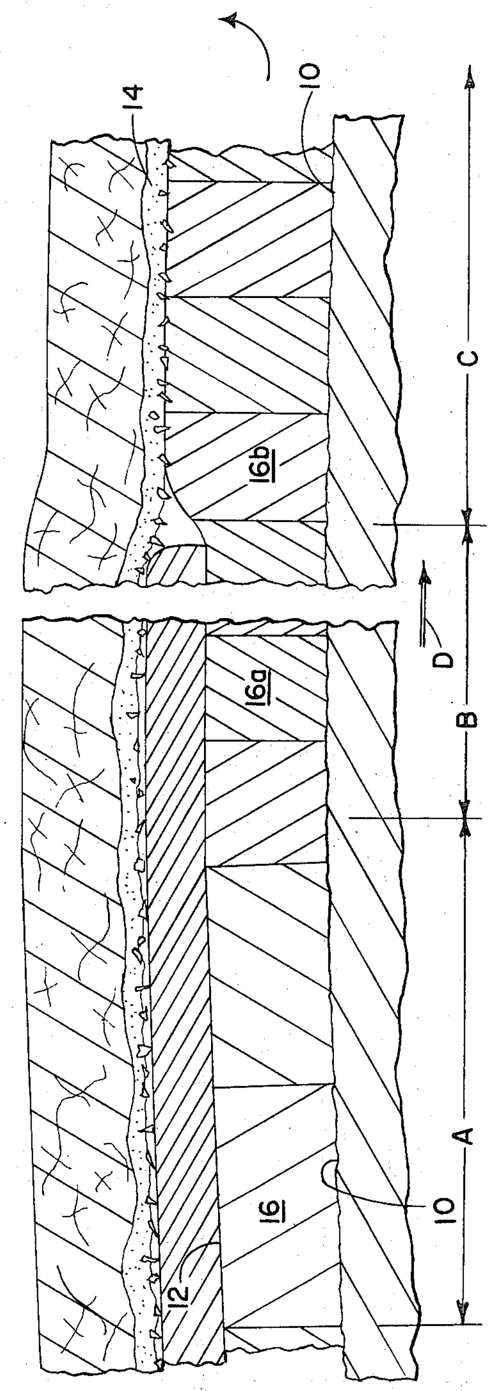


FIG 5

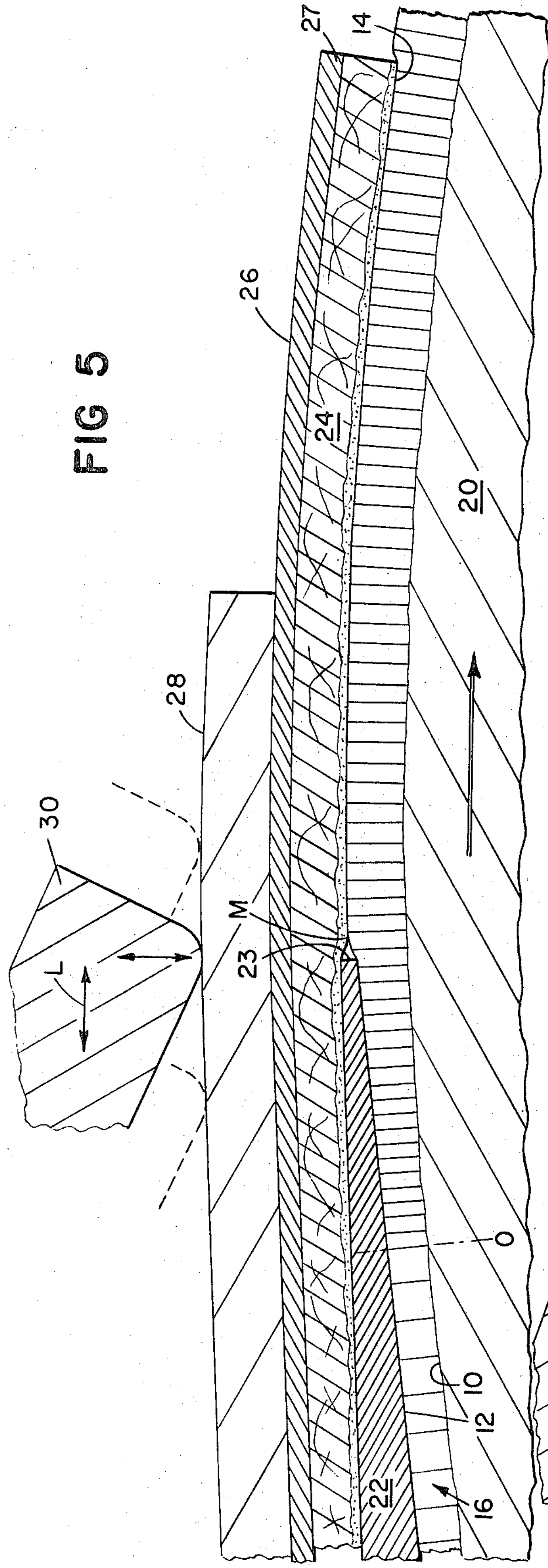

27
14
26
24
20
28
30
L
M
23
O
10
12
22
16

FIG 7

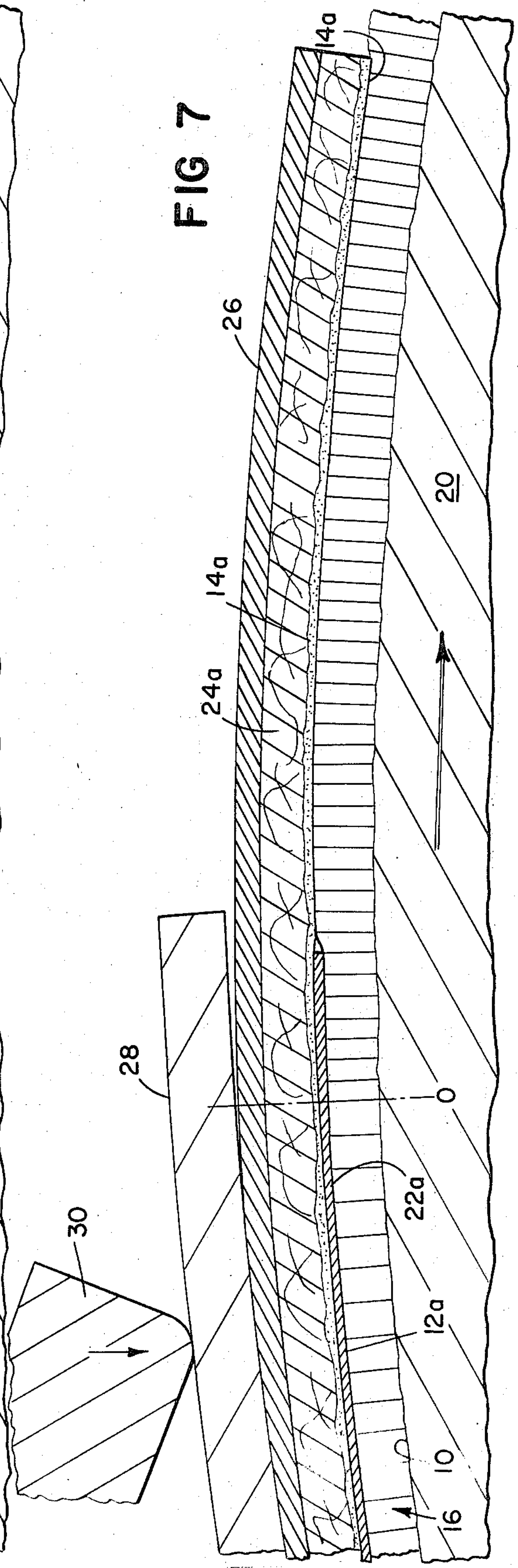
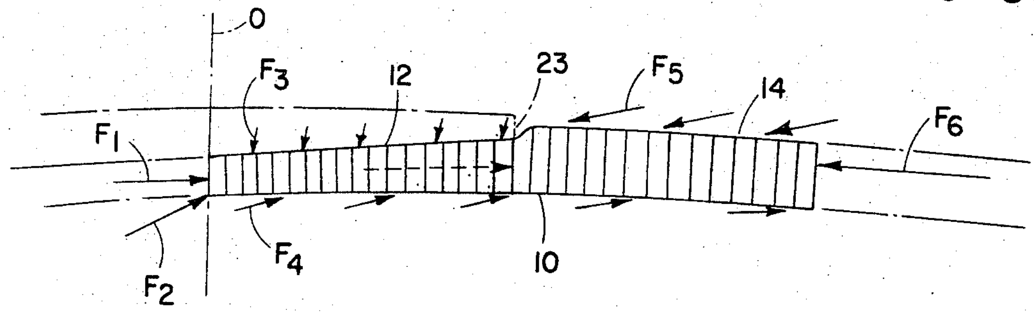

14a
26
20
14a
24a
28
O
22a
30
12a
10
16

FIG 5a



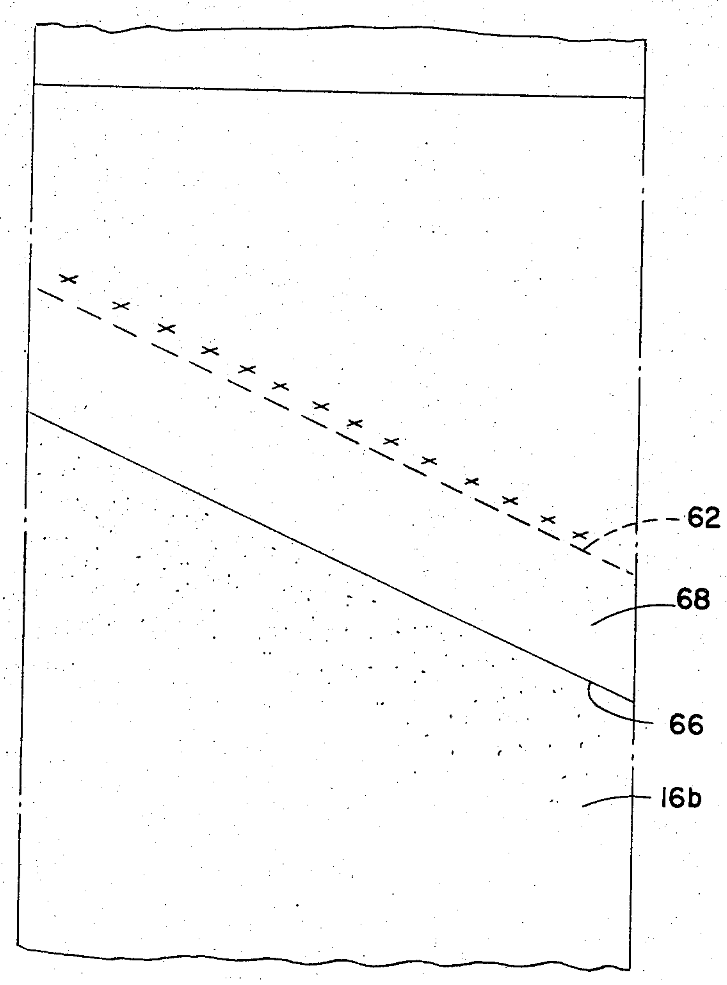


FIG 12

FIG 6

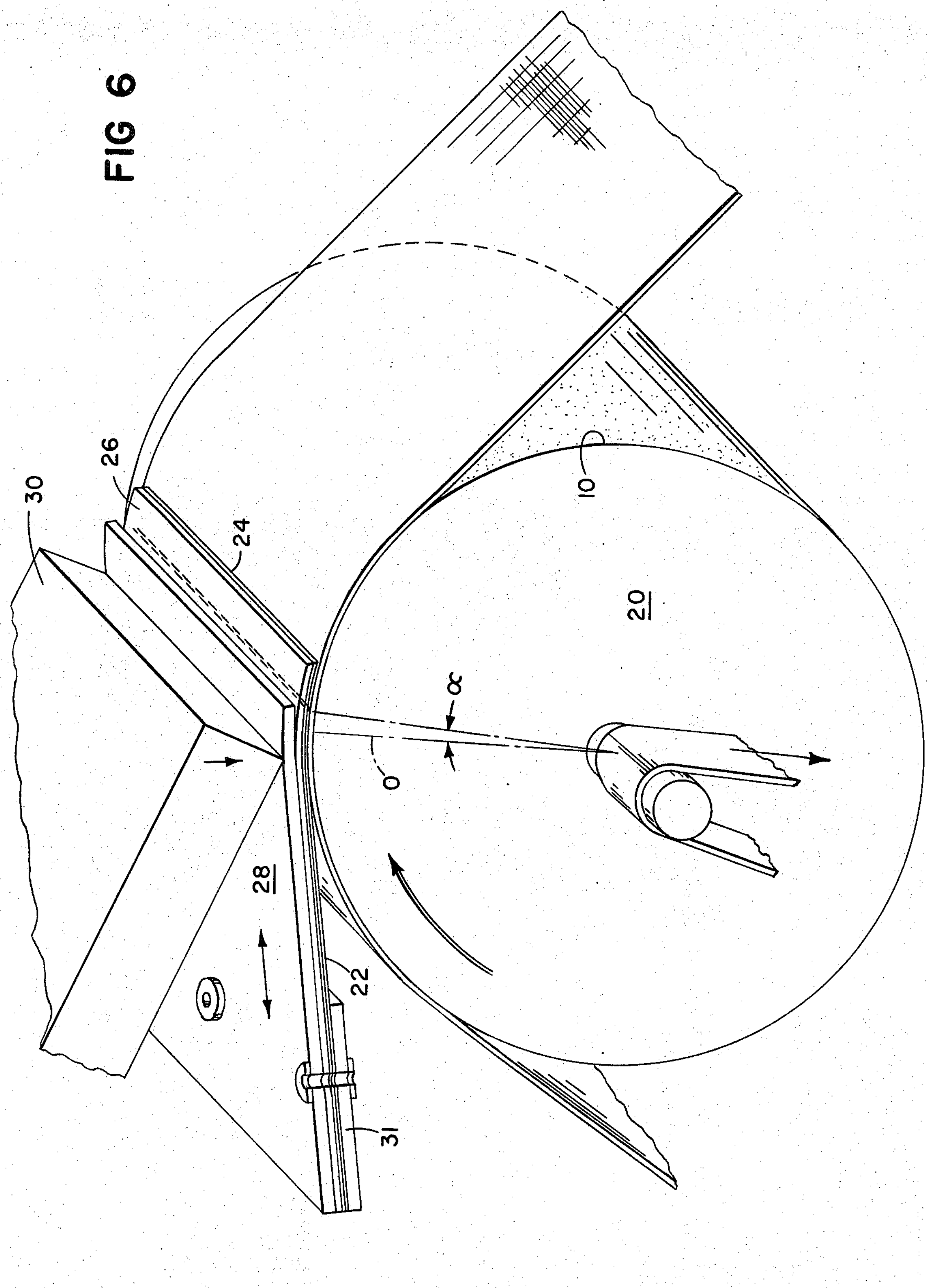
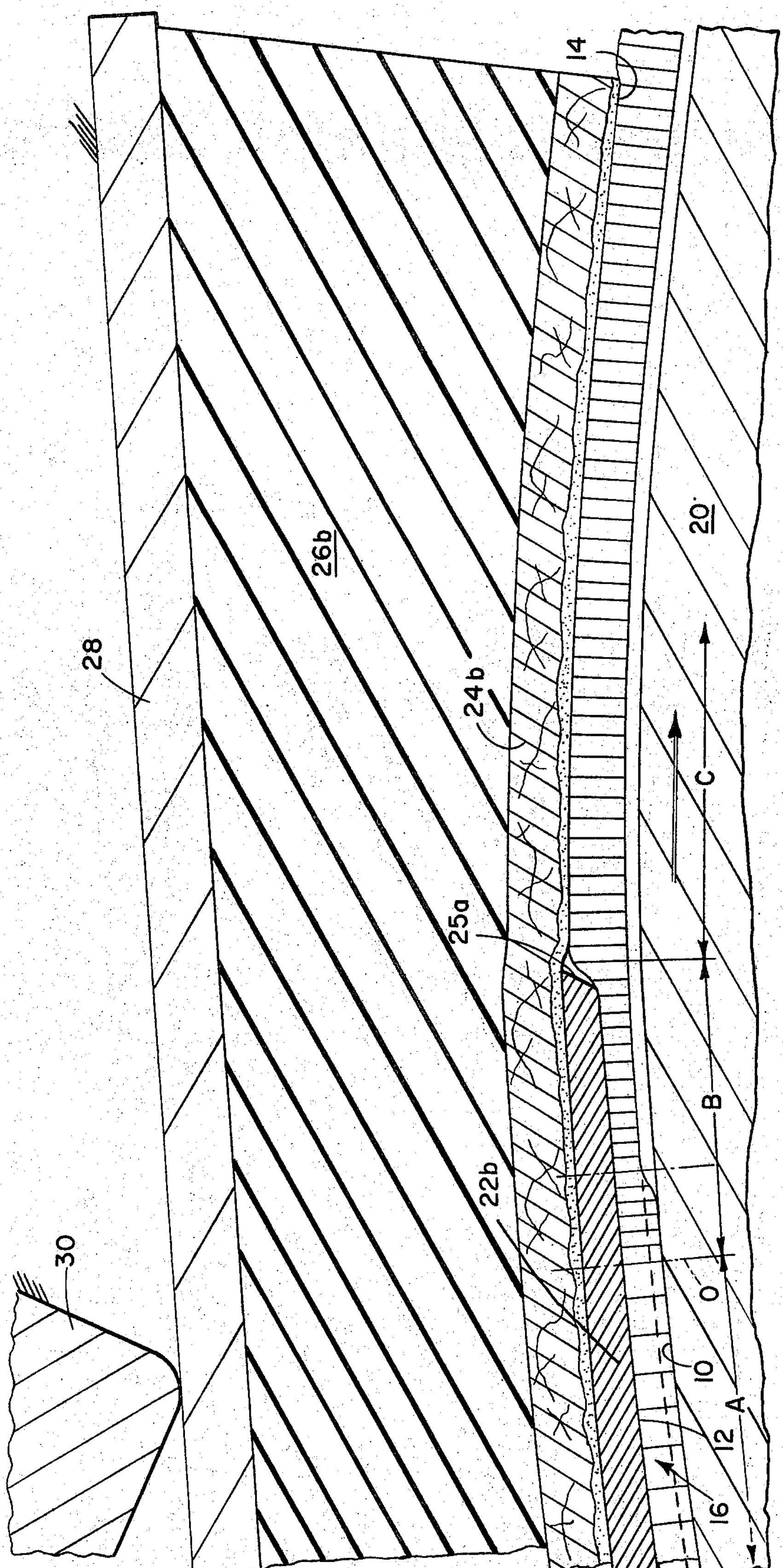


FIG 8



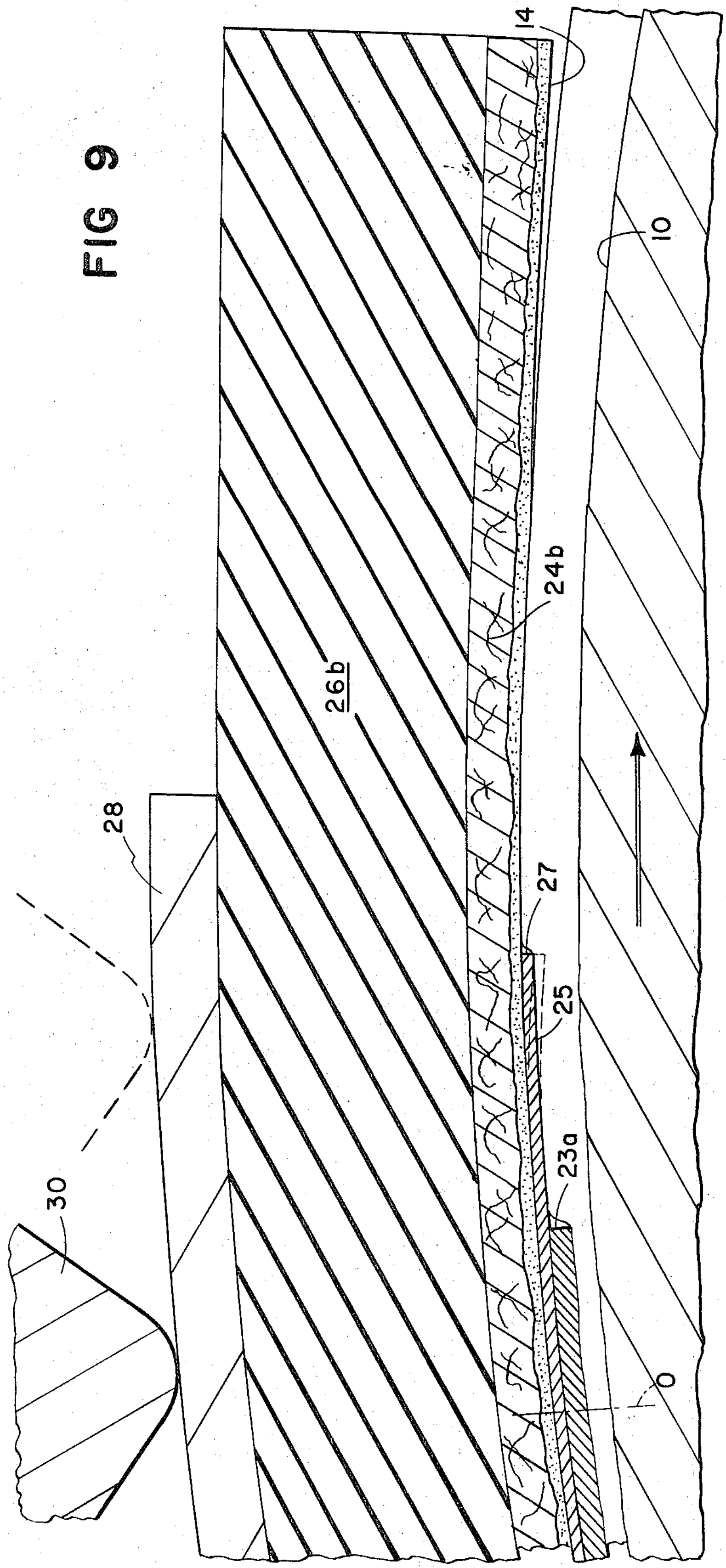


FIG 9

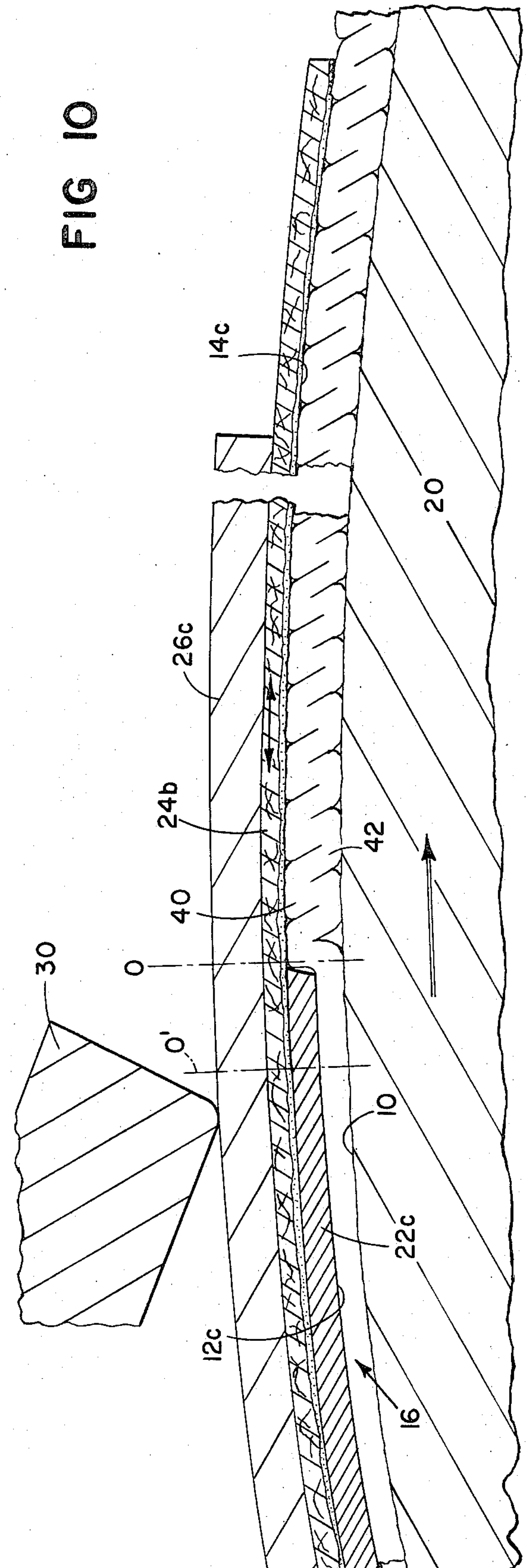


FIG 10

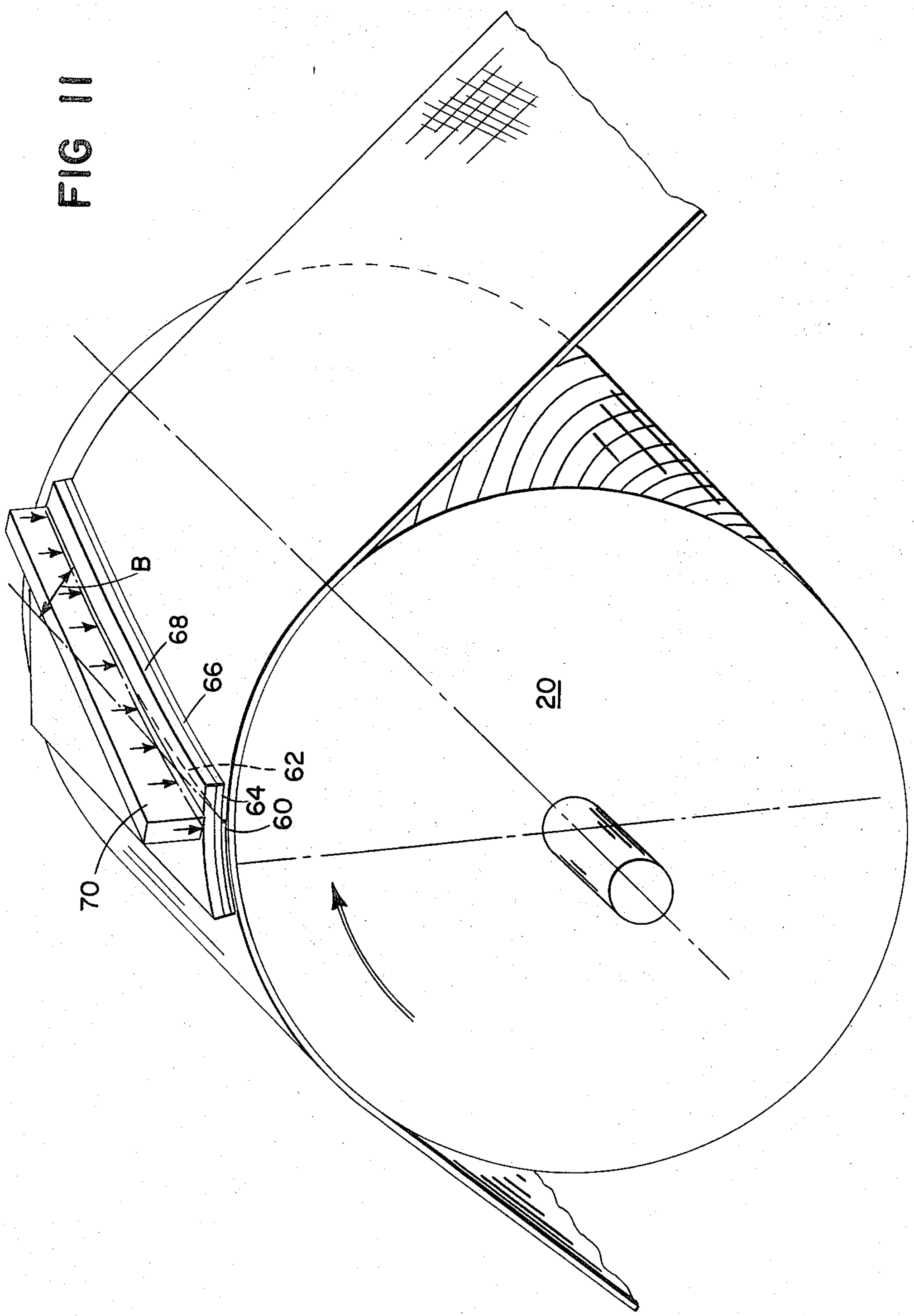


FIG 11

FIG 13

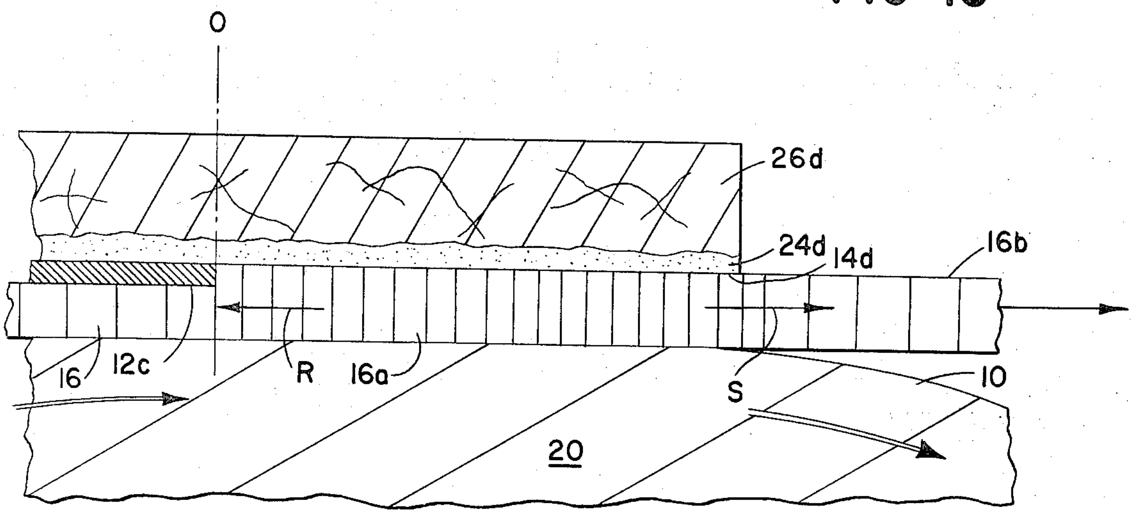

O
26d
24d
14d
16b
16
12c
R
16a
S
10
20

FIG 14

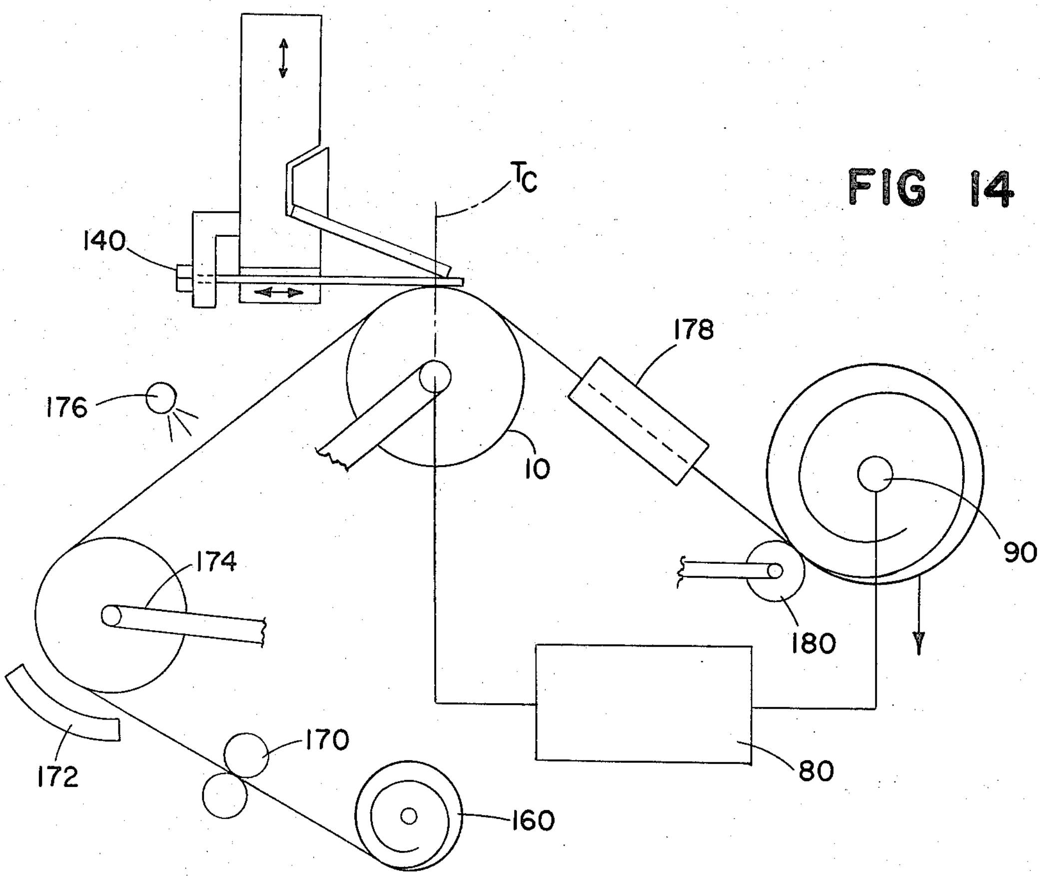

T_C
140
178
176
10
90
174
180
170
172
80
160

FIG 15

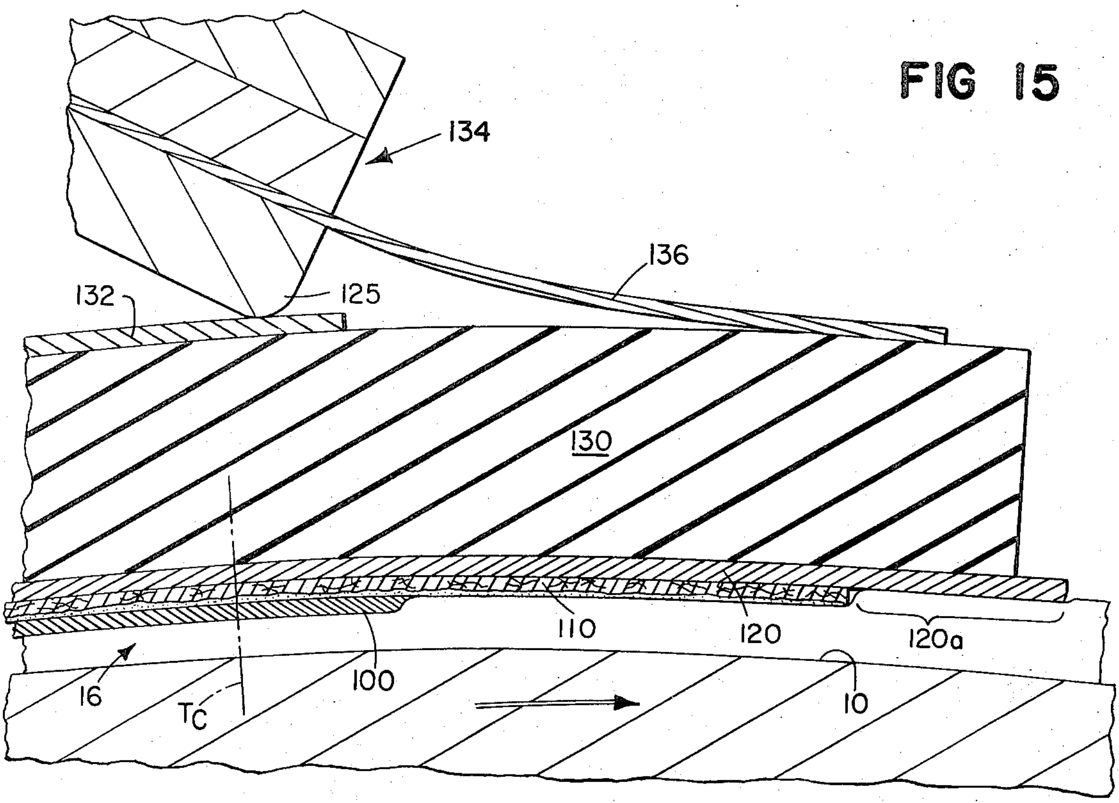
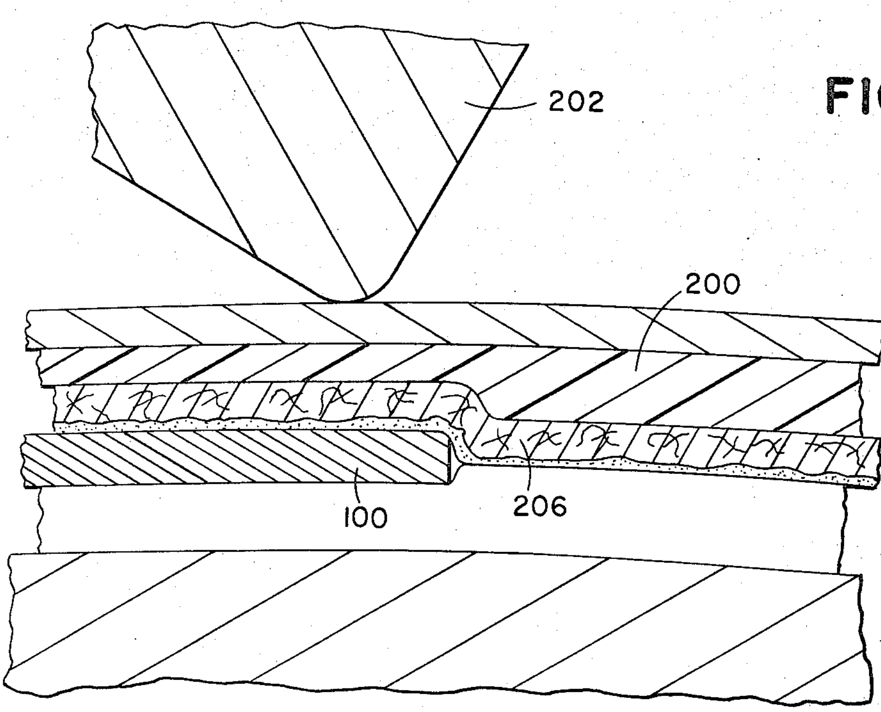


FIG 16



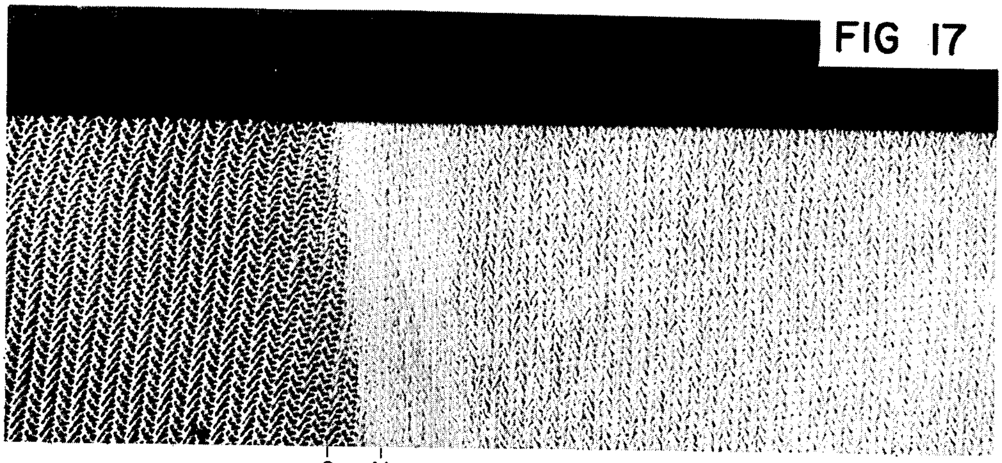


FIG 17

O M M

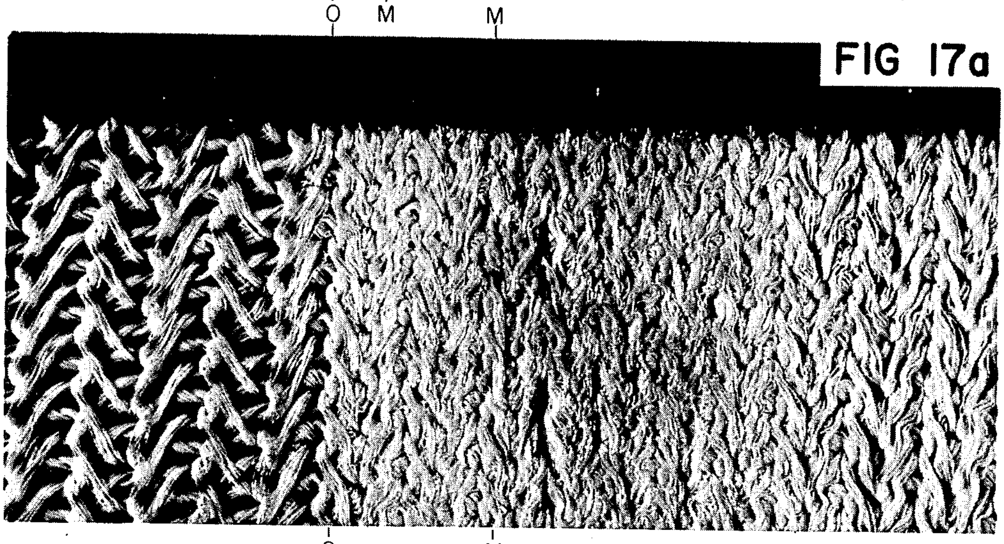


FIG 17a

O M

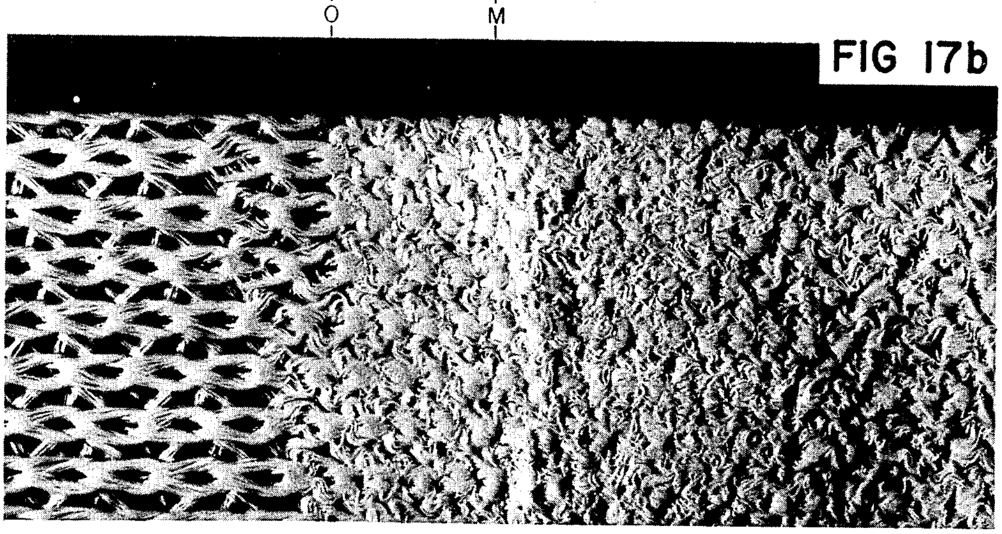


FIG 17b

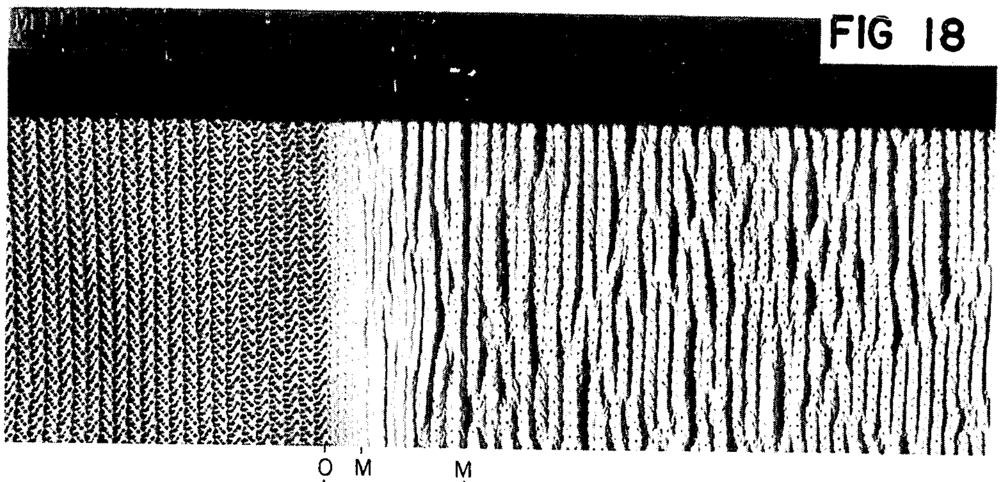


FIG 18

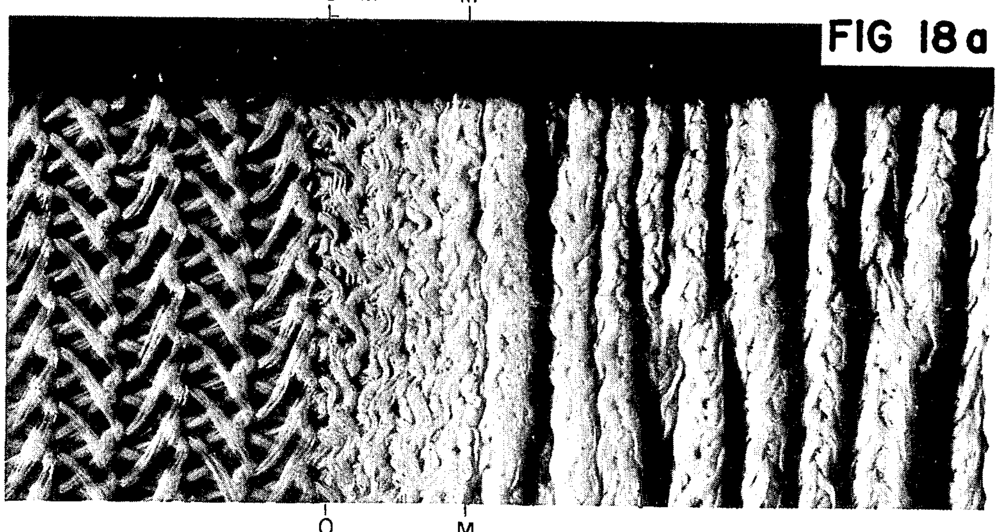


FIG 18a

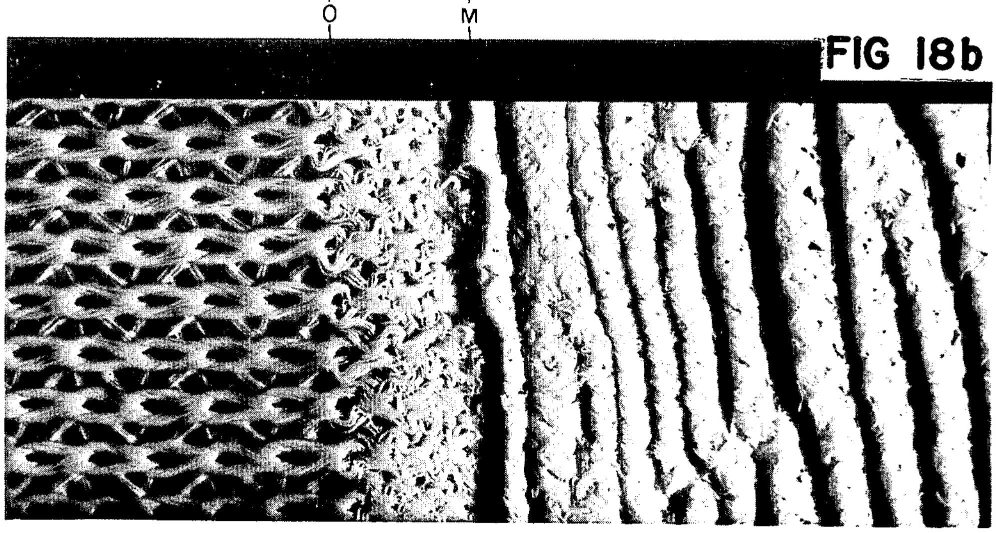


FIG 18b

METHOD AND APPARATUS FOR LONGITUDINAL COMPRESSIVE TREATMENT OF FLEXIBLE MATERIAL

This invention relates to longitudinal treatment to produce desired effects in thin materials such as woven, knitted and nonwoven fabrics, yarns (which may be a warp of side-by-side yarns), papers, films, foils and other webs and strands of deformable material. The effects obtained include improvements in hand, softness, cover, thickness, bulk, ability to drape, and extensibility.

At the present time, in spite of numerous attempts over many years by workers in the field, so far as we are aware there are essentially only two compressive treatment processes in commercial use (leaving aside the age-old method of creping by scraping a web from a drum by a doctor blade). These are the well-known "Sanforizing" process involving longitudinally compressing the material by the retractive action of thick moving belts which straighten after passing around a roll, and the machines of our earlier work all of which are still in use commercially, some more extensively than others. See U.S. Pat. Nos. 2,765,513; 2,765,514, 3,260,778, 3,066,046, 2,761,490, 2,915,109 as well as others.

It has been the purpose of our work over many years to create a machine and process that would go beyond experimentally demonstrating desired effects to provide the key to practical operation, with leeway to tolerate variables that occur. In this way we have been successful, and a number of machines employing different principles we have developed are in operation in mills today.

We have recognized, however, that use of longitudinal treatments of thin materials would greatly increase if there were a practical machine and process which could be used on very wide webs, e.g., 10 feet wide and more; could operate at high speeds, e.g., for papers and nonwovens at speeds of 300 feet per minute and higher; could tolerate a wider range of temperatures, e.g., from ambient up to 200° to 400° F. without affecting the relationship of the machine elements; would not involve rapid wear of parts so as to operate for needed lengths of time without adjustment; would not require high accuracy of alignment; as a standard machine design, could be used on a wide variety of materials and treatments; would increase the degree of treatment obtained; and which could be simple and capable of operation by personnel of average skill.

It is an object of the present invention to provide a machine and process meeting these needs and capable of producing uniform effects while accommodating variables of the materials such as density, thickness, uniformity, temperature-sensitivity, limpness and prior history.

Other objects are to realize effects not heretofore realized on a practical commercial basis and to make other effects easier to obtain.

Specifically it is an object to provide an improved machine and process that can uniformly alter a web by forces exerted essentially only within its plane.

A very specific object of the invention is to provide a method and means for improving the cover and bulk of textile materials and the hand and texture of such materials as paper and nonwoven products.

The invention concerns machines having opposed members for contacting respective sides of the material, in the case of uniform treatment of webs the members normally being uniform across the width of the travelling web. According to the invention, on one side of the material is located a drive member providing a movable drive surface and on the other side there is a retarder member spaced from the movable drive surface and having a retarding surface to engage the exposed face of and retard the material while the material is exposed to the drive surface. On the same side as the retarder member is a primary material confining member immediately preceding the retarder member and defining an inlet to the space between the retarder member and the drive surface. The primary member has a preferably smooth confining surface engaging the exposed surface of the material to cause the material to be driven forwardly by the driving surface and is at least in part spaced closer to the driving surface than the retarding surface. The retarding surface is provided with a multiplicity of portions operable successively to grip and release the material thereby to locally retard the material in its passage between the drive surface and the retarding surface, and the retarding surface is further characterized in being essentially non-extensible in the direction of travel of the material.

In one form of the invention we provide a resilient means supporting the retarder member in the direction of the thickness of the material being treated.

In any of the forms of the invention the retarding portions may comprise projections formed of hard grit grains bonded to a non-extensible backing sheet or may be defined by hard metal.

The movable drive surface, according to the invention, may be the surface of a rubber roll, or the knurled surface of a steel roll, or the roughened surface of a travelling belt, or otherwise be provided by a member having suitable frictional material engaging characteristics.

When the machine is adapted to treat compressible materials the drive member and primary member are arranged to drive the material in essentially uncompressed condition to an initial treatment point wherein compression thereof commences prior to its reaching the retarding surface, the confining surface being further positioned to define with the drive surface a passage beyond the initial treatment point, the parts being positioned to slidably confine a compressed column of material in the passage and direct the same forward for exposure to the retarding surface.

For treatment of some materials all portions of the retarding surface which engage the material are spaced at least as far from the drive surface as the portion of the retarding surface which first effectively retards the material. For treating compressible materials, we may use a drive surface comprising a surface having ridges and grooves, the grooves having a component in the direction of travel of the material and providing at the initial treatment point spaces in which the material may initially slide backward relative to the drive surface and compress before leaving the grooves.

In an embodiment for treating compressible materials, the drive surface is of cylindrical form and the retarding surface commences less than 10 arc degrees from the initial treatment point.

In many cases the member defining the retarding surface may comprise a fabric or be a layer member, the drive surface being curved and the machine having a bent metal member over the retarder member positioning the retarding surface with respect to the driving surface. In the latter case a backing layer of resilient material may lie over the retarder layer member and in either case the bent metal member may comprise a resilient or non-resilient sheet form metal keeper member over the backing layer.

In other embodiments the retarder member is a sheet form member, and a presser member is provided for pressing toward the drive surface at a point above the region where the primary member ends, the position of the presser member being adjustable backward or forward relative thereto in the direction of travel of the material so as to vary the proportion of force it applies upon the primary member and upon the retarder member.

The primary member may comprise a sheet of deformation-resistant metal, the body thereof having a first thickness and tapering or stepped to a reduced thickness at its forward edge, the retarder member overlying the primary member and extending downstream over and beyond the trailing edge of the primary member.

In another form of the invention the retarding surface is backed by a layer of a material deformable in the direction of the thickness of the primary member and deformed about the trailing edge of the primary member to position the retarding surface with respect to the drive surface. In this case the machine may include an outer sheet form member of deformation resistant and force-transmitting material overlying the layer, and a presser having a pressing surface engageable with the outer member positioned to transmit pressing forces to a predetermined region beneath the confining surface or beneath the retarding surface or beneath both such surfaces through the thickness of the intervening members. The presser includes mechanism for adjusting backwardly or forwardly the position of engagement of the presser with the outer member in the direction of travel of the material.

In machines for treating compressible materials wherein the material is advanced to an initial treatment point and then through a passage between the confining surface and the drive surface to the retarding surface, the passage may be enlarged in the direction of the thickness of the material to permit creping of the overall sheet of the material, the machine being thereby capable of producing a time-varying densification of the material under the confining surface as the resistance of the column of compressed material varies with the varying stages of crepe formation. In this case the surface defining the enlarged portion of the passage may be continuous with the confining surface or separately formed. Likewise, at least immediately preceding the retarder member, the spacing of the surface defining the enlarged portion of the passage may be substantially greater than the spacing of the confining surface from the drive surface in the region immediately preceding the initial point of treatment, enabling expansion of the material in the direction of its thickness before reaching the retarder. In either case, the spacing of the confining surface from the drive surface within the passage may abruptly increase and the increased spacing extend all the way to the retarder member. Likewise, the confining surface may be provided by more than one member in overlapped relation. The

time-varying densification of the material may alternatively be made to occur by providing an abrupt enlargement in the direction of the thickness of the material of the spacing between the retarding surface and the drive surface immediately downstream of the trailing edge of the confining surface rather than in the aforementioned passage. For some effects abrupt enlargements may be provided both in the passage to the retarding surface and in the region under the retarding surfce.

To achieve other special effects the primary and retarder members may be arranged at an angle to the path of travel of the material, so that the trailing edge of the confining surface and the leading portion of the retarding surface are angularly disposed to the path of travel of the material. This arrangement may be employed both in embodiments wherein the drive member is a roll, in which case the edges define a helical segment upon the surface of the roll, and in embodiments wherein the drive member is planar, as an endless belt. When a belt is employed and the treatment occurs in a planar section thereof, the adjustments of relative pressure between the driving surface and the other surfaces may be made by mechanisms pressing against the back side of the belt.

The invention also features the method of treating a travelling length of flexible material comprising confining the material against a moving drive surface by means of a confining surface so that the material will be driven forward in essentially uncompressed condition to a point of initial treatment and providing a retarding surface on the same side of the material as the confining surface but beyond its trailing edge and in spaced relation to the drive surface. The retarding surface is essentially non-extensible in the direction of travel of the material and has a multiplicity of portions operable to successively grip and release and thereby to locally retard the travelling material, while the confining surface is at least in part spaced closer to the drive surface than is said retarding surface. The forwardly driven material while still uncompressed and beneath and engaged by said confining surface is caused to impinge upon a column of already compressed material at the initial treatment point and is then propelled as a continuously formed column of compressed material from beneath the confining and retarding surfaces.

For treating textiles, the retarding surface may be arranged to nap the surface of the material in the process of retarding it.

The method of the invention is applicable to bulking or softening a length of fibrous material by providing the driving surface with material gripping projections. The material is slippably confined against such driving surface and at least portions thereof pressed into the intervals between the projections by the confining surface; the relationship of the surfaces is maintained such that the driving surface slides with respect to the material so that the projections tend to pull fibers at one side of the material forwardly and out of the intervals while the rough surface has a relatively opposite effect on fibers at the other side of the material.

To achieve certain effects with some materials the method of the invention includes the step of slidably confining the material substantially to its original thickness at a point of initial treatment, and then releasing the compressed material to expand its thickness at a point spaced beyond the point of initial treatment. The method may include slidably confining the material following the initial treatment point at a spacing greater than the respective spacing at such point with a low friction confining surface prior to exposing the material to the rough retarding surface.

The invention also contemplates a method of treating a travelling length of flexible material including confining the material against a moving drive surface by means of a confining surface so that the material will be driven forward by the drive surface, providing a retarding surface which is essentially non-extensible in the direction of travel of the material and located on the same side of the material as the confining surface but beyond it trailing edge and in spaced relation to said drive surface and wherein the confining surface is at least in part spaced closer to said drive surface than is said retarding surface. We cause the forwardly driven material while still uncompressed and beneath and engaged by the confining surface to impinge upon a column of already compressed material at an initial treatment point beneath the confining surface located upstream of the trailing edge and propel the continuously formed column of compressed material from beneath the surfaces.

In all forms of the invention, the material may be drawn out from the end of the effective retarding surface at a rate greater than the unassisted rate of extrusion from the machine, thereby controlling the geometry of the passage and the degree of treatment.

The foregoing and other objects, features and advantages of the invention will be apparent from the following detailed description of presently preferred embodiments thereof taken in conjunction with the accompanying drawings wherein:

FIG. 1 is a diagrammatic highly magnified perspective view of a preferred embodiment of the invention;

FIG. 2 is a diagrammatic view of higher magnification than FIG. 1 of the action of a projection of the retarding surface upon a fiber or thread;

FIG. 3 is a diagrammatic, highly magnified vertical cross-section of a preferred embodiment treating a knitted fabric and

FIG. 4 is a plan view of the fabric at various stages of treatment; with FIGS. 3 and 4 having the points of treatment aligned;

FIG. 3*a* diagrammatically illustrates the directions of the forces believed involved at the point of exit of the material from beneath the retarder.

FIG. 5 is a highly magnified cross-section view of a preferred embodiment of the invention including the members defining the effective surfaces; FIG. 5*a* is a diagrammatic cross-section and force diagram, illustrating forces acting upon the material in FIG. 5; FIG. 6 is a perspective view on a smaller scale of the effective parts of the machine of FIG. 5;

FIGS. 7, 8, 9, and 10 are views similar to FIG. 5 of other embodiments of the invention;

FIG. 11 is a view similar to FIG. 6 illustrating a retarding assembly curved along the axial extent of a drive roll;

FIG. 12 may be regarded either as a plan development of the surface of a drive roll, illustrating an embodiment similar to FIG. 11 or a plan view of a machine employing a planar drive surface;

FIG. 13 is a diagrammatic view illustrating a double action effect of the rough retarding surface in a softening or other such treatment;

FIG. 14 is a diagrammatic view of an overall machine operable according to the invention;

FIG. 15 is a view similar to FIG. 5 of another preferred embodiment;

FIG. 16 is a cross-sectional view similar to FIG. 5 of another preferred embodiment;

FIGS. 17, 17*a*, and 17*b* and FIGS. 18, 18*a*, and 18*b* are photographs of materials treated according to the invention.

DETAILED DESCRIPTION

In FIG. 1 there is diagrammatically shown a driving surface 10 moving in the direction of arrow D, a confining surface 12 and a retarding surface 14. It is assumed for this figure that surface 10 is provided by a moving member and both surfaces 12 and 14 are provided by stationary members, none of which are shown. A web of flexible material 16 to be treated is shown over the moving drive surface 10 and under the confining and retarding surfaces 12 and 14, all of these surfaces having a uniform widthwise extent corresponding to such width of the web as is to be treated uniformly. The degree of magnification of this view will be understood from the fact that the actual thickness of the material is usually less than 0.015 inch and sometimes less than 0.005 inch. Where a curved drive surface is employed, its radius of curvature may be 2 to 6 inches. The degree of compression of the material at its various stages is illustrated in a diagrammatic manner by the sections which are intended to represent equal masses of material.

The confining surface is adapted to slippably engage and press the material against the drive surface to confine and drive it forward in region A in longitudinally uncompressed condition to point O, the initial point of treatment.

The machine is shown in running condition after the treatment has stabilized. It will be appreciated that starting conditions may be quite different. The retarding surface 14 lies along the driving surface 10. The confining surface 12 is at least in part closer to the driving surface than is the retarding surface 14. The retarding surface 14 is rough relative to the confining surface 12 and commenses at T, in this embodiment, within one inch (for textile materials of the order of 0.005 inch to 0.015 inch thick within about one-fourth inch) of the point O. (In other embodiments e.g., with stiff materials, the initial point of treatment may be nearly coincident with the initial point of the effective retarding surface).

At the point of treatment the longitudinally uncompressed material is driven against a column of temporarily or permanently compressed material, maintained in retarded state by the retarding action of rough retarding surface 14. The material, as it leaves confinement under confining surface 12, is freed to expand at least somewhat, and is able to remain in its expanded condition throughout its transit under retarding surface 14. Through the cooperation of the roughness of that surface, with its relatively large spacing from the drive surface, the retarding action can be maintained with light downward pressure, without danger of causing refeed due to excessive pressure of the web against the drive surface and without undue wear of the retarding surface where wear would cause a detrimental change in the treatment. Advantageously, from the initial area of contact of the retarding surface with the material, the effective retarding surface lies substantially parallel or diverges relative to the drive surface, or at least does not constrict the compressed material or require it to extrude through a minimum passage.

The material illustrated in FIG. 1 is compressible, for instance it could be knitted nylon tricot, or a host of other textile and textile-like products. For many treatments of such materials the transit of such materials at point T from under confining surface 12 to the retarder surface involves a latent tendency for the material to curl upwardly and back, in response to the dragging action of the confining surface, with resultant balling up and jamming of the material. This tendency is defeated by the location of the initial treatment at a point substantially in advance of the transition to the retarding surface. As shown this is accomplished with an extension of the confining surface through passage B, in which is confined a column of longitudinally compressed material. Thus the initial treatment of the material occurs within the confines of the confining surface 12 where the material is significantly densified, achieving greater columnar strength, and also acquiring a tendency to expand. When this column reaches transition point T at the end of the passage, its strength resists the tendency to buckle, while its newly acquired expansion tendency causes it to expand up against the regarding surface. Densification at least to some degree within the passage B is a critical requirement for numerous textiles which otherwise would not acquire the necessary columnar strength before encountering the retarding surface, while it is essentially non-critical, but in some cases desirable to achieve certain effects, in the case of denser materials already possessing the requisite columnar strength.

According to the present invention, the retarder is substantially rougher than the roughness of the confining surface either before or following the initial point of treatment, and in many instances is preferably rougher than the drive surface, all measured in the direction of travel of the machine.

Preferably for textiles and textile-like materials the roughness of the retarding surface is in the range of 100 to 500 RMS (Root Mean Square microinch) while for paper and paper-like products the roughness is in the range of 200 to 800 RMS (the particular roughness selected will vary with the relationship of all operating surfaces and the nature of the material and its desired treatment).

In comparison a preferred confining surface has a roughness under 20 RMS and a preferred drive surface for textiles comprising a roll coated with tiny hard particles has a roughness less than 100 RMS and for papers a roughness less than 130 RMS.

The length of the retarding surface is not critical over a considerable range, being in general longer than the length of such densification passage B as is used, or the distance between initial treatment and initial effective retardation. In certain instances, however, especially dealing with treatment of stiff materials and employing roughnesses in the higher part of the range, the length of the retarding surface in region C may be varied as a control for the nature of the treatment obtained. In other instances, e.g., for bulking textiles while minimizing shortening, it is also desired to shorten the retarding surface and have it rougher than would be the case where a substantial amount of longitudinal shortening is affirmatively desired.

A wide variety of materials may be used to provide the retarder projections or retarder surface roughness of the invention. The retarding surface must be essentially non-extensible in the direction of travel of the material in order to perform the proper retarding effect and obtain uniformity and other advantages. For many treatments it is essential that the retarder member also be resiliently supported in the direction of the thickness of the material, which helps to obtain a self-adjusting proper geometry. The elements defining the projections or the roughness preferably comprise hard, wear-resistant material. Preferably the material forming the retarder surface has an elongation of less than 5 percent under tensions of 1,000 psi.

Materials, such as filled urethane, which have dense and stable surfaces, exhibit the property of retarding by slip-stick action and with long wearing properties.

It is advantageous to many treatments that the retarding surface not only have its retarding effect, essential for the application of longitudinal compression to the material, but that it also have a napping effect, by which it is meant that the retarding surface should momentarily interlock with the material locally to the extent that the material is locally deformed. Referring to FIG. 2, which is a fragmentary, diagrammatic, highly magnified cross-sectional view, a projection P of the retarding surface 14 engages a thread or fiber F of the material undergoing treatment and causes it to be separated and deformed from the yarn or bundle Y to which it originally conformed. This effect, multiplied thousands of times over each small area of the material, advantageously contributes to the total treatment, for instance, where it is desired to soften and improve the bulk or cover of nylon knitted fabrics, or to give non-woven fabrics softeness and a better hand or drape.

Referring to FIGS. 3 and 4 a treatment of knitted nylon tricot, 40 × 40 denier, ten thousandths of an inch thick is illustrated. In region A the longitudinally uncompressed fabric 16, illustrated by a single chain or wale in the plan view of the face of the fabric in FIG. 4, is driven forwardly to the point 0 of initial treatment. Here it is confronted by a column of longitudinally compressed or densified fabric while it is still confined by a slippable confining surface in region B, in this case by the smooth extension of the confining surface 12. Within the length of one chain loop the fabric is converted from an elongated uniform chain, in which the threads of the yarn are tightly bundled together (region A) to a densifed condition where tht total density of threads is increased while the individual fibers are buckled and bent away from each other, although still retaining a recognizable bundle outline (region B).

After the densified fabric 16a slides to the end of the confining surface 12, it expands and is contacted by the rough retarding surface 14 which has a napping characteristic. Here, in region C, the longitudinally unyieldable roughness of the surface 14 penetrates into the body of the fabric to apply retarding forces sufficient to retard the material and maintain the compressed column in region B. The fabric continues to be driven forward in region C, causing relative movement of the fabric under and past the projections of the retarding surface, the movement under the retarding projections being somewhat analogous to a ratcheting movement.

While this occurs, the retarding surface is also effective to nap the fabric by dislodging individual threads from their bundles and displaying them in a more random condition. The treated fabric **16*b*** has a barely if at all recognizable chain structure, and the fabric (despite being originally formed of straight nylon monofilament) has now a soft and textured appearance.

In this example the untreatd fabric may have a thickness of for instance 0.010 inch and the thickness of the treated fabric may range from a slight increase up to 0.020 or 0.030 inch thickness depending upon a number of factors within the control of the operator.

Where it is desired mainly to bulk or thicken a textile, and not to shorten it, advantageously the effective length of the retarding surface **14** is kept short, i.e. one-eighth or one-sixteenth inch in length, and the thickening occurs at the end of the confining surface. The material is subjected to severe shearing forces at its surfaces, causing actual rearward stretching or even localized tearing of the top surface relative to the bottom surface. These forces and shear distortion are illustrated acting on a section of the material in FIG. **3*a***. When the material emeges from under such a short extent of retarder it immediately "blooms" into a bulky form, and has a distinct tendency to roll back in the direction of the curved arrow shown in FIGS. **3** as a result of the oppositely acting forces upon the face and back of the material, such forces and their directions being indicated by the straight arrows.

In important instances it is required that the body of the fabric not be visibly creped, it being desired to achieve treatment of the threads and yarns individually. We have made this possible by the densification of the fabric in region B in which the columnar strength of the fabric is increased while the material is tightly confined at its faces before it is exposed to the retarding surface. With maintenance of this geometry the fabric is resistant to bodily buckling as it is pushed through the successive passages.

Referring to FIG. **5** a non-creping treatment with moderate bulking is achievable with the construction shown. The drive surface **10** is formed by a cylindrical roll **20**, of a diameter on the order of 4 inches for treatment of narrow width materials, up to about **1** foot width, and of increased diameter for wider webs. A sandwich of stationary elements extends over the roll from a stationary support not shown, at the left in FIG. **5**. This sandwich includes a primary member **22** whose lower surface defines the confining surface **12**, a nonresilient fabric member **24** having a coated grit facing (e.g., emery cloth) defining retarding surface **14**, and a relatively thick and unyielding keeper sheet **28**. A spring steel keeper **26** is inserted between keeper sheet **28** and the member **24** and extends along the back of the latter. It has an unstressed curvature of a radius less than the radius of the roll **20**. The entire sandwich extends as a cantilever over the roll and a presser member **30** is adjustably positioned over the sandwich to press it against the roll. As indicated by the arrows the presser member is adjustable toward the roll surface to vary its pressure and it is adjustable relative to the sandwich back and forth in the lengthwise direction of the latter, to vary the relative point of application of pressure. By the latter adjustment the proportion of downward force applied to the confining surface to the downward force applied to the retarder member beyond primary end **23** is variable in an action we refer to as "teeter totter." The forces applied to the confining surface are normally much greater than those applied to the effective retarding member, and an adjustment one way or the other of the presser member of **.025** inch in the direction of the travel of the material can have a desirable effect in controllably varying the treatment. Such adjustment affects the degree to which the emery member deforms about the end **23** of the primary. To some extent it also shifts the point M of initial effective contact of the emery with the material to be retarded.

In the embodiment of FIG. **5** the primary member **22** is formed from a sheet of invar metal originally of 0.020 inch thickness, having a slope ground to form a lower surface which causes the forward part of the member to taper from the full thickness down to the end **23** of 0.004 inch over a distance of approximately one-quarter inch. The retarding member **24** comprises emery cloth having an uncompressed thickness of about 0.010 inch, and with the rough surface of the emery facing against the top surface of the member **22**. The emery extends beyond end **23** a distance e.g., of one-eighth to three-eighths inch depending on the treatment and roughness of the emery chosen. The keeper **26** is a length of spring steel of 0.005 inch thickness, and one-half inch width, bent in the widthwise direction on a radius smaller than the radius of the drive surface, and having its width arranged in the direction of travel of the drive surface.

With application of pressure by the pressure member **28** as shown, in the region of end **23** of the primary, the confining surface **12** is pressed tightly toward the drive surface and effects forward drive of the material **16**, without longitudinal compression, up to an initial point of treatment **0** under the confining surface **12**. The material is compressed against a column of longitudinally compressed material which is confined by the forward extension of the confining surface. As the material proceeds forward under this tapering extension, the material is able to gradually expand while being channeled forwardly without opportunity to buckle bodily upon itself. When it reaches the end **23** of the primary member it has stabilized as a lengthwise moving column of nearly the same height as the height under the retarding surface. It therefore readily bridges the small space at the end **23** of the primary member and engages the retarding surface **14** at point M while moving nearly parallel thereto. From point M the retarding surface itself resists any tendency of the material to turn up, while at the same time the retarding surface applies retarding forces in the manner described previously.

The effect of the spring keeper member **26** is to maintain the retarding surface in the approximate curvature of the drive surface without at any place permitting the spacing under the retarding surface to narrow down or constrict the column in the region of effective retardation. In fact, with this embodiment, although loading of the pressing edge of presser member **30** may be around 50 pounds per linear inch of presser edge widthwise of the machine, one can easily raise the forward edge **27** of the spring keeper **26** with one finger, illustrating the relatively light downward forces required while enabling the rough retarding surface to perform its function. With this arrangement therefore the treated material retains substantially its fully expanded thickness throughout the length of the retarding surface.

The fore and aft adjustability of the relative position of the presser member on the sandwich, indicated by arrow L in FIG. 5, enables a control of the pressure applied by the retarding surface **14**; through the force transmitting action of rigid keeper **28** and spring keeper **26**, increased pressure on the retarding surface has the effect of increasing the over-all retarding force and the degree of treatment.

In FIG. 5 as in the embodiment of FIG. **1**, the point **0** of initial treatment is close to the beginning of the retarding surface, for the knitted tricot specifically mentioned this dimension being one-eighth inch or less. In general for treatments where substantial longitudinal compression is desired of densifiable materials, the length of the retarding surface is substantially longer, but not necessarily so where bulking or napping are the effects to be achieved.

In certain instances, as with nylon tricot, the drive surface is heated and transfers heat into the material in region A to prepare it for treatment. After treatment it is desirable to continue application of the heat to set the material in its new form.

Referring to FIG. 5*a* (which is adjacent FIG. **12** in the drawings) principal forces which are apparently acting upon the material in the embodiment of FIG. **5** are illustrated. Force F_1 represents the impact of the material against the column of compressed material at the point of initial treatment. This force is generated through the gripping of the material by the driving surface at points preceding point **0**, these forces being transmitted through the uncompressed material. F_2 represents the further driving force attributable to the portion of the driving surface in the region of point **0**. It represents the fact that the gripping effect of the drive surface upon the material must be overcome by the retarded column of compressed material in order for compressive treatment to commence and for the drive surface of the roll to slip freely forward under the compressed column. F_2 has a slight upward component representing the upward wedging effect of the gripping projections of the roll surface as they slide forward.

F_3 represents the confining forces exerted by the confining surface **12**. The compressed column of material has a tendency to expand in all directions, an effect which can be considerable when the material being treated has a resilient consistency. F_3 has a slight rearward component representing the drag effect. The smoothness of the confining surface (e.g., roughness less than 20 RMS) and its low coefficient of friction, assisted e.g., by a teflon impregnation, help to keep this drag effect small.

Throughout the exposure of the material to the moving drive surface **10** there is a slight tendency for that surface to pull the material forward, represented by force F_4. This pull is a function of the pressure with which the material presses against the drive surface. As indicated above, e.g., in the discussion of keeper **26**, this pressure can be very light, keeping force F_4 small.

When the compressed column moves from under end **23** of the confining surface, it expands and immediately engages the rough retarding surface **14**, whereupon a significant retarding force is applied along that surface. The localized retarding forces at points along the retarding surface are represented by F_5 while the cumulative effect of the retarding surface downstream beyond that shown is represented by F_6.

In this connection it is to be noted that because the retarding surface is essentially non-extensible in the machine direction, its projections remain stationary under the force exerted by the moving material and prevent non-uniform retarding patterns or bunching to occur; this feature also causes the force applied to the projections to produce an upward turning couple, i.e., a forward force on the projection produced by the material, and an equal reaction force acting rearward along the thickness of the emery, this tendency being yieldingly resisted by a vertically resilient support. Note that this turning tendency varies during treatment and produces a self-adjusting effect to provide uniform treatment.

It is found that with the shortness of the treatment zone as mentioned (region B, FIG. **1**), the forces can act together to dramatically alter the structure of the material, the degree of treatment varying with the selection and relationship of the various elements. With curved drive surfaces it is to be noted that the limited arcuate extent of the region B assures that the major forces applied by the drive surface preceding or at the point of initial treatment **0** are substantially aligned with the passage under the rough retarding surface, and thus can more readily cause the material to move therethrough without buckling.

In increasing order of the degree of treatment the following retarding surfaces have been employed in the arrangement of FIGS. **5** and **5*a*** for treatment of knitted and other textiles, all of these retarding members being emery cloth sold by Behr Manning of Troy, New York, under the tradename Metalite, having a thickness on the order of 0.010 inch.

description	RMS new	RMS in use
crocus cloth (polishing cloth with fine abrasive grit)	100–130	90–110
500 J	200–240	170–200
400 J	270–300	230–270
320 J	300–500	230–280

These roughness readings were made with a profilimeter on the abrasive side of these materials, the side which is ordinarily disposed against the material. Durable fabric of essentially inelastic qualities may itself be used as a retarding surface; one such demonstration employed a tightly woven mesh fabric having a profilimeter reading of 450–650 new, 400–450 used. Metal screening and other materials having the requisite gripping characteristics may also be used.

Another point worthy of mention is the discovery that used emery surfaces which appear worn-out in fact have a very desirable effect and are actually preferred. When new emery surface is employed it is preferable to pre-treat the retarding surface by rubbing toilet tissue or other fibrous material on the emery, to leave a deposit of tiny fibers. We are not fully sure why this has good results, but it is believed that the fibers duplicate the condition, for new emery, of the emery in use, where certain free fibers serve somewhat as a lubricant over the roughest portions of the surface. The "lubricating" effect of retained fibers is demonstrated especially in the small region where the emery bends about the end of the primary member. It is usually preferred to have the emery surface lie parallel to the drive surface or to slightly diverge all along its effective length. But in order for the emery to reach its initial point of effectiveness at the desired height, it usually must be bent down over the end of the primary member. The latter in some cases is as thick as 0.005 to 0.010 inch or more. Undue retarding is avoided at this initial sloped portion of emery apparently because of an increase of retained loose fibers that accumulate on the sloped surface.

For many treatments the roll surface should not be as rough as the emery surface; the above embodiment employs a drive surface having a roughness ranging between 80 and 90 RMS.

Referring to FIG. **6**, there are shown the working components of a machine in accordance with the invention. The roll is steel and its gripping characteristics is achieved by a plasma coating of tungsten carbide; it is driven in the direction of the arrow, receiving material to be treated on the left side and delivering treated material to the right. The sandwich includes a support plate **31** and the aforementioned primary member **22**, retarding member **24** (non-resilient, high tensile strength emery cloth), upper keeper member **28** and spring keeper **26**. These are all clamped together and mounted in a support (not shown). In this embodiment the presser member **30**, although adjustable vertically for adjustment of pressure, is not shown adjustable horizontally. The relative horizontal adjustment between presser and the sandwich is achieved by movement of the sandwich support in the direction of the arrows, to achieve the teeter totter adjustment as desired.

The limited arcuate extent α (less than 10°) of the spacing between the initial point of treatment of the material and the commencement of the effective retarding surface enables the substantial alignment of driving and retarding vectors (see FIG. *5a*) which is believed to contribute significantly to the nature and controllability of the treatment.

Referring now to FIG. **7**, using this embodiment the treated material can be confined substantially to its original untreated thickness. In this case the confining surface is defined by the primary member **22***a* which is extremely thin, e.g., 0.002 inch thickness (which may be supported by the retarding member **24***a* lying directly above it). The retarding member comprises a fabric with a suitable wear-resistant surface **14***a*. The other elements may be the same as in the preceding embodiment. The incoming material is pressed against the drive surface by the primary confining surface **12***a*, compressing the material in the direction of its thickness but not in the longitudinal direction. As it proceeds, it is confronted by the column of longitudinally compressed material and treatment occurs, with probable lifting of the primary to a slight extent, but not allowing the expansion afforded by the tapered primary of FIG. **5**. The surface of the retarding member in this case is smoother than in the preceding case, so that not so much longitudinal densification of the column occurs. Where the treatment is employed mainly for physical working or softening of the material, even this amount of compression may be pulled out further along in its movement, so that the resultant product need not be shortened much from its incoming state.

While the invention of course is not limited to any one material, it is helpful to an understanding of the invention to pursue the same material through a number of treatments to show some of the effects that can be obtained. Those given so far have referred to nylon tricot. An embodiment similar to FIG. **7**, with a primary member 0.004 inch thick, a rougher emery, e.g., metalite **280J** of short extent beyond the primary, e.g., one-eighth inch, can be used to bulk the same nylon tricot from 0.010 inch to 0.015 inch thickness with shortening of less than 15 percent and good softness and cover on both sides, with temperatures around 250°F or higher.

Using the embodiment of FIG. **8** an extreme degree of bulking of the fabric is possible. A nylon tricot material of 0.010 inch thickness was bulked to a thickness of 0.026 inch, with a fleecy felt like consistency; when the material was stretched to remove some of its longitudinal compression it retained its bulky character to a significant degree.

In FIG. **8** a roll provides the drive surface **10** which is defined by a series of side-by-side knurls and grooves extending at an angle of 50° to the axis of the roll. The knurl grooves have a depth on the order of 0.005 inch.

The primary member **22***b* comprises invar of .012 inch thickness, the retarding member **24***b* a sheet of emery designated **320J** with a surface roughness of 280 RMS, a flexible keeper member **26***b* in the form of a medium durometer silicone rubber of one-eighth inch thickness and a Swedish blue steel upper keeper member **28** engaged by the presser member **30** as described above.

Employing the same nylon tricot material as used for the preceding examples, the material is pressed against the drive surface in region A, in this instance the material being pressed into the grooves so that the ridges are formed in the material which the roll pushes forward. As the material reaches the initial point of treatment **0**) it still fills the knurls, and the first action is for the roll to slip forward with the material sliding back relative to the knurl, while at the same time being driven strongly forward. Soon the action of the following knurl projection and the confronted column of densified material wedges the material out of the knurl, and up against the extension of the confining surface. As it proceeds forward the faster advancing knurl surface provides momentary expansion spaces so that the net space accommodating the compressed column exceeds the clearance space between the confining surface and the imaginary cylindrical surface projected through the outer tips of the knurl projections. Thus even under the primary member there is produced a column of considerable thickness, which has inherent resistance to buckling. The end **25***a* of the primary member is cut at a 45° angle sloping upwardly forwardly, and this helps to ease the expanding material out from under the confining surface **12** and to direct it forward into contact with the retarding surface. Also it is suspected that the nature of the compressive action achieved by the knurls at point **0**, which is at an angle across the face of the material, results in ridges of high compression in the material itself, which arrive progressively at the sudden opening from under the primary. Thus a portion of a given ridge which has already progressed under the rough retarding surface and confining portion of the given ridge still lying under the confing surface, restrain that portion of the ridge which is emerging at **25***a*, and prevent backward curling or other movements that might promote buckling and unwanted crepe in the body of the material as a whole.

In this embodiment, as in the foregoing, the drag exerted by the material on the retarding surface and the fact that the substance of the retarding member is dimensionally stable, wear-resistant and therefore not detrimentally extensible under working loads, keeps the retarding surface in position without any unpredictable narrowing of the passage or other actions which would make the process difficult to maintain under mill conditions.

Rubber behind this emery cloth or other dimensionally stable sheet on the other hand has virtue in helping to conform the emery to the curvature of the drive roll, along the length of the retarding passage. It also helps conform the emery about the edge **25***a* of the primary member, decreasing the size of any open space in that region—and helping in that regard to combat the problem of unwanted creping and to position the beginning of the effective length of the retarder surface. In cases where the desired effect is to bulk a web, the keeper member **28** may be very thin, and allow the retarder assembly to flex upwardly. In such instances the portion of the retarding surface nearest the confining surface accomplishes most of the retarding, outward portions serving to buffer the column to ensure uniform treatment across the web width.

FIG. **9** is an embodiment in which essentially two steps of treatment can be accomplished before the material is exposed to the retarding surface. Where, as is the case with many knitted and other materials, the material is not dense, i.e., is porous or loose, densification of the material in the longitudinal direction takes place at an initial point of treatment preceding the end **23***a* of the primary member. A column of longitudinally compressed but not substantially thickened material extends from **0** to primary end **23***a*, under the extension of the primary surface. Following edge **23***a* a second extension **25** or roof of low friction slippable material, invar or teflon impregnated blue steel, extends forward. The column of material, despite its tendency to curl upward, is guided forward instead by oblique contact with this low friction surface; meanwhile the natural tendency for the material to expand in thickness causes the column to fill the volume under the roof. This thickened column (now having more resistance to bend bodily because of increased thickness) is then projected forward under edge **27** of the roof and into exposure with the retarding surface, where it further expands and is napped as described above. This device has also demonstrated the capability of bulking nylon tricot, and is particularly effective when used with the knurled roll referred to in FIG. **8.** The length of the keeper **28** may be as long as the emery and stiff where high compaction is required; where high bulking with lower compaction is desired, the shortened keeper shown, or a thinner keeper is employed, thus shortening the effective length of the retarding surface.

The length of the roof for treating nylon tricot is preferably in the range of about 0.030 to 0.080 inches length; with a drive roll of 4 inch diameter, 0.040 inch roof length is preferred, with a roll of 12 inch diameter, 0.060 inch roof length is preferred.

In certain instances it is advantageous to adjust the presser **30** forward, e.g., to the dotted line position. In this case the extension **25** is bent downward and causes more densification to occur. In a similar arrangement, but with a much longer extension **25,** the extension itself may serve as the primary and define the point of initial treatment, and by this construction a simple throwaway package of emery and extension may be removably inserted between relatively thick permanent members.

In other instances from those mentioned above, it is desired to impart a crepe or surface treatment to the body of the material as a whole. Referring to FIG. **10,** a creping action is illustrated. For use with hard and stiff materials such as a non-woven fabric or water laid or laminated type, a drive surface **10** of a roughness of the order of 110 to 130 microinch RMS is employed, formed by tungsten carbide particles bonded to a steel roll surface. For non-wovens, ranging from 0.005 to 0.015 inch thickness a primary member **22***c* of 0.010 inch thickness is employed. Also for such hard-surfaced materials an emery retarding surface **14***c* of grit size on the order of 320 mesh or less is employed. Over the emery a keeper **26***c* of Swedish blue steel plate of 0.010 inch thickness is employed, and for use with wide sheets a drive roll of 12 inch diameter is employed.

The nonwoven may be dense enough itself to be driven forward for the treatment desired at point **0,** but in other instances as with other textiles, densification may occur under the primary surface in the manner described in the foregoing embodiments, with the initial treatment at point **0′**. When the web is driven forward from under the primary it enters a substantially widened space and due to forces acting previously upon it, as well as the resistance of the retarded column, it tends to turn up.

In doing so it engages the projections of the retarding surface moving at a substantial angle against the plane of the emery. The projections, together with the confronted column of retarded material, are effective to momentarialy stop this material. Meanwhile, more material is forced forward from under the primary surface. Since the preceding material has curled to the upper part of the space, the subsequent material folds forward beneath it. With still more material being forced into the spaced by the continuing action of the drive surface on the densified sheet, the folded material is pushed forward and the cycle commences again. The result of this action is a series of folds in which the upper portions **40** of the folds slant backwardly and the lower portions **42** slant forwardly, due to the action of the projections of the retarding surface.

As in the preceding embodiments the emery surface does not converge or form a restriction along its effective length, the projections of the emery being sufficient to retard while the emery surface is maintained throughout at a distance from the drive surface greater than the spacing of the confining surface from the drive surface.

When treating non-dense materials to a creping or other treatment which creates either small, localized folds or larger folds, the intermittent action as pictured in FIG. **10** affects the degree of densification occurring under the confining surface. When the bottom leg of a crepe fold lies at the end of the primary, as shown, a first resistance force is transmitted back to the initial treatment point **0.** When the material collapses upwardly to form the next crepe, the resistance force suddenly decreases. This has its effect in the densification occurring under the confining surface, the degree of densification varying along the length (i.e., with time) with the varying stages of the creping action. This can have desirable effects both for decorative appearance and physical qualities of the material.

Referring again to FIG. **10,** the member **24***b* is adjustable in the machine direction, as indicated by the arrow, thereby providing a means of controlling the degree of densification and longitudinal compression of the crepe column, e.g., in cases of using coarse emeries, by adjustment of the amount of emery extending forwardly beyond the edge of the primary member.

The action of the emery, even upon paper and non-woven articles, includes a napping effect in which fibers of the web along the upper surface of the web are individually retarded, and rearranged, imparting softness and change of appearance to the web. The action of the emery, along with the other surfaces, also is to carry out the treatment in an accurately maintained geometry, with the desired, but no more than desired, thickening of the web and coarseness of the folds.

For use on non-woven materials, the following emery surfaces, for instance are useful, manufactured by 3M Corporation under the trade name TriMite.

Grade	Roughness
180 C	500–600 RMS
320 TE6	200–350 RMS

The material-contacting surface **12***c* of the primary member **22***c*, in comparison, had a roughness of less than 20 RMS.

For treating material at an angle to its direction of travel the embodiment of either FIGS. **11** or **12** may be employed. They differ in showing different preferred drive surfaces. In each instance a primary member **60** defining the confining surface has a forward edge **62** set at an angle to the axis of the roll and also curved or flexed to conform to the roll; that is to say at an angle to the projection of the axis on to the roll surface. In FIG. **11** the edge is in a plane set at a constant angle, thus describing a helical segment upon the roll surface. The retarding member **64** projects beyond that edge and terminates in a further edge **66** also set at an angle to the axis, lying parallel to primary edge **62.** A suitable keeper means **68** lies over the retarder member and a presser member **70** also set at the same angle presses the assembly against the drive roll. Treatment with this machine has a widthwise as well as length-wise effect, and successive passes through two such machines, but with the machines having the angle set in opposite directions, can impart two-way stretch and other two-way qualities to the material being treated.

Referring to FIG. **13** and **14,** there is shown diagrammatically a system in which the longitudinal treatment has substantially no effect upon the length of the treated product. As in the preceding embodiments, such as FIG. **10,** the material **16** is driven forward against a column of compressed material **16***a* and is thereby compressed either by densification, folding or a combined effect, and the rough surface **14***d* of the retarder **24***d* is effective to uniformly retard the column of compressed material even when the material has such hard surfaces as do paper and paper-like products. Thus the length of the column of compressed material may represent an uncompressed length of twice the extent. In this embodiment however a drive device **80** (FIG. **14**) coordinately drives the drive surface **10** at e.g., only 2 percent faster surface speed than take-up roll **90.** The effect of the take-up roll, after running conditions are established, is to pull upon the material and take up e.g., 98 percent as much length as has been fed to the machine.

The rough retarding surface **14***d* now has a further function in providing resistance to the pulling tendency of the take-up roll **90,** joining with it to form a stretching means in which material, when released from the column, is stretched e.g., to nearly twice its compressed length, as indicated by numeral **16***b*.

Referring to FIG. **13,** in magnified view, it is thus seen that the effect of the rough retarder surface is to upply a compressional resistance R and stretching tension S at opposite ends of the retarding passage. In between, the projections of the rough retarding surface momentarily lock or ratchet upon the moving column and retain it in position so that both compression and stretching can proceed in a uniform manner.

As an example a stiff paper-like non-woven fabric of 0.015 inch thickness and a "boardy" feel was processed. This non-woven consisted of a lamination of five layers, a layer of scrim threads, sandwiched between two non-woven wet laid sheets and two external sheets of tissue paper. The resultant product after treatment was very soft and had good draping qualities, with numerous lines representing the tiny crepe that had been applied and then removed.

In FIG. **15** there is shown another arrangement for softening non-woven fabrics. The primary member **100** is a 0.010 inch thickness Teflon impregnated Swedish blue steel sheet, the retarding member **110** is a dimensionally stable sheet of **180J** emery, slightly greater than 0.010 inch thick, and a further blue steel member **120** of 0.008 inch thickness lies above the emery and extends beyond the trailing edge thereof. Above this member is a resilient member **130** comprised of one-eighth inch thickness natural rubber and above it lies a final 0.010 inch thickness blue steel keeper plate **132.** The presser member **134** comprises three 0.050 inch thickness plates, cantilevered to form a presser edge **125,** and a 0.010 inch auxiliary presser **136** extends forwardly therefrom, helping to conform the assembly to the curvature of the drive surface **10.** The latter is provided by a steel roll of 12 inch diameter having a rough surface formed by tungsten carbide particles bonded thereto, with a roughness of 130 RMS. The edge **125** of the presser member presses upon the keeper **132** at a point one thirty-second inch forward of the top center, Tc, of the roll, the assembly projecting forward from a support to be tangent to the roll at Tc in the unstressed condition as shown in FIG. **14.** The end of the primary **100** is approximately aligned with the edge **125** of the presser member, the emery extending forward thereof a distance of approximately five-sixteenths inch. To adjust the relative position of the presser member adjustment screws **140** (FIG. **14**) can move the assembly, including the primary, forward and back relative to the presser member.

The extension **120***a* of the metal member beyond the emery can serve to press the web against the drive surface to refeed the web and pull out some of the compression in the web where this is desired. It has the virtue of effecting this tension while resisting the tendency for the web to narrow or "neck in" during pulling.

Referring back to FIG. **14** again, examples of coordinate treatments are shown. The supply roll **160** feeds the web to corrugating roll pair **170** which forms fine longitudinal corrugations. Examples of other pretreatments are the radiant heater **172,** the steam heated or chilled roll **174** and the steam, water or chemical spray **176.** Following the treatment, a dust collector and treater **178** and a heat set or chill roll **180** are shown.

Referring to FIG. **16** there is shown a backing member **200** of special properties. Under the first application of compression of the presser member **202** it permanently deforms into a thin rigid load transferring member, which helps in assuring positive drive of the material. At the end of the primary member **100** it is deformed and conforms the emery **206** about the trailing edge thereof. However, its extension beyond the trailing primary edge, is under much less compression and behaves as a resilient member, giving the preferred support to the retarder surface. One such suitable material is a leather substitute sold by Dupont under the name "Corfam."

FIG. **17** is a photograph of considerable magnification of that side of a treated material which engaged the drive surface. The point of initial treatment O, under the confining surface is spaced a short distance from point M, the point of initial contact with the effective retarding surface (slightly beyond the end of the primary member indicated by T in e.g., FIG. **1**). FIGS. **17***a* and **17***b* are views of greater magnification respectively of the back and face of the same treated fabric.

FIGS. **18, 18***a*, and **18***b* similarly show the same kind of material which has been treated by being creped.

These examples were prepared by stopping the machine in the midst of treating, and leaving the presser member and the other members in place under full operating load. The drive surface heat over this duration fused the fibers in the state in which they were found, thus preserving the relationship as defined by the machine.

In other embodiments numerous other specific details may be employed. For example, as a durable retarding surface a thin metal mesh or metal or other hard fiber weave may be employed in which the crossing elements form projections; or a finely perforated dimpled or scratched metal plate may be employed with the surface discontinuities at the openings forming surface roughness; or a rough-surfaced metal plate may be employed having, for instance, tiny tungsten carbide particles adhered thereto through the plasma coating technique or more preferably, the gun shot technique. Other durable materials may be employed, such as hard and durable fabrics.

The particular roughness to be employed will be determined to a large degree by the particular product and process in question; thus for knitted fabric roughnesses around 100 to 200 RMS are appropriate, and for hard kraft papers roughnesses of 600 RMS or above are appropriate; but other roughnesses will be appropriate for other materials and other treatments.

In preferred forms the retarder defines a general or closed retarding surface, but in some instances a multiplicity of brush or needle-like projections may be employed as the retarder. In one such instance a multiplicity of retractable needles, or a card clothing arrangement of projections can be employed to provide a first degree of retardation at start up of a process, with predetermined retraction to achieve a lesser degree of retardation during the running conditions. (In another arrangement card clothing projections can also be arranged to define the confining surface.)

Another control of retardation lies in the take-up device, it being possible by proper rate of takeup to remove the treated material to control both the final shortening of the product and to some degree the geometry of the retarding surface where it is resiliently supported in the direction of the thickness of the material being treated.

Other factors involved in retardation are the amount of pressure applied against the retarding surface and the length of the effective retarding surface. Actually, use of very light pressure on the retarding surface is operable, it being sufficient to hold the retarding surface to approximate the form of the driving surface or even to diverge therefrom, following the initial point of contact of the retarding surface with the material. It is one of the advantages of the invention that the column of compressed material need not be necked down or forced to extrude through a minimum passage—where high wear can occur—the generally parallel but rough surface being sufficient to maintain the compressed column in position. In situations where this is critical, it is possible to control the degree of treatment by change in the roughness character of the retarding surface or in the lengthening or shortening of the effective exposed length by a suitable adjustment device or by controlled rate take-up of the material.

The characteristics of the drive surface are also to be determined in the light of the particular process and result desired. It is possible to drive textiles with less drive surface roughness than is required for hard-surfaced materials such as kraft papers and plastic or metal films and foils. Other considerations may concern the interaction of the drive surface and the particular material employed, and thus in some instances a smooth roll may have an adequate driving characteristic for a particular treatment, for example in the case where the material or the drive surface has or is given adhesive qualities. The roll in such case may be very smooth, but in most cases it is desired to be rough or prickly, and in certain instances such as described above, grooves in the drive surface can contribute desirably. A significant advantage of the invention lies in its elimination of a blade or doctor to retard the travelling web. The use of such a blade is a limiting factor in choosing the surface characteristics of a drive roll. If the roll is too rough, it will produce rapid mutual wear of both roll and blade; if too soft, e.g., rubber, it will cause the blade to dig into the roll surface. According to the present invention this limitation disappears and any desired driving surface characteristic may be employed, such as projecting knobs, smooth rubber, knurls, etc.

The nature of the primary or confining surface is of consequence, and in general should be smooth and be of a material having a low coefficient of friction. Also, the invention permits high speed operation, and in certain instances the friction heating of the low friction confining surface can be a factor, leading to the choice of Teflon impregnation or use of other materials having favorable, low coefficients of friction. The nature of the desired treatment also influences the construction of this primary or confining member. Where the preferred layer form of primary and overlying retarder members are employed, the thickness of the primary member sets the spacing of the emery at the tip of the primary. Where it is desired to impart a gross crepe or decorative pleated effect, these can be obtained simply by choice of an adequate thickness of the primary member. However, where such gross crepes are to be suppressed, it is desired to avoid any abrupt large spacing. At the same time it is often desired to have thick primary members so that they can be handled with ease by mill personnel without danger of damaging them. Getting the emery down to the appropriate spacing for initial contact with the material is facilitated by the tapered margin on a thick plate according to FIG. 5, and the use of a conformable material as a backing according to FIG. 9.

Where it is desired to achieve special effects, this primary member may be slotted or grooved, to provide discontinuities or variations in the treatment, and similar variations can occur in the retarder area.

Pretreatment of the material can have important effects, and the nature of possible treatments is made quite wide because of the invention. Thus a pretreatment with a lubricant such as a silicone spray is possible to ensure smooth movement of sticky and other difficult materials; the retarding effects of the projections or of the rough retarding surface being still operable even in the presence of such treatment substances.

Temperature control is to be observed for temperature-sensitive products. Thus in the case of making nylon tricot stretchy in the machine direction temperatures of pretreatment or during the treatment may be maintained slightly below the softening temperature, e.g., at 350°. However, for the purpose of improving cover and bulk without so much permanent densification, it is found that operation at around 250° F for this particular material has distinct advantages. In the case of cotton knit, controlled prestretching and steaming are essential to ensure proper plasticity and dimensional stability.

In the case of papers and numerous other products, it is important to maintain a suitable moisture content to ensure uniform production; in such cases humidity chambers or other such pretreatments are indicated, with or without chemical treatment and temperature control. Much, as we have said, depends upon the final result that is desired.

Important advantages are also obtainable with mechanical pretreatment of the materials. In one important instance materials to be "worked" or rendered stretchy in the cross as well as machine direction are pretreated to have a multiplicity of fine corrugations running lengthwise of the material. These longitudinal flutes after passing under the confining and retarding surfaces can result in a two-way stretch or softening of the material.

Post-treatment of the materials to preserve or take advantage of the properties obtained from the present machine and process are also advantageous. Tension treatment and heat setting are perhaps most common, but chemical treatments, chilling and special coatings are also of advantage in numerous instances. It is to be noted in this connection that in certain instances the main elements of the machine are useful. Thus where a heated roll is employed to define the driving surface, an extended first portion of the confining surface can assist in preheating the material and/or an extended portion of the retarding surface can assist in continuing to confine the treated material against the roll after treatment, for purposes of post-heating.

In another preferred embodiment, instead of a driven roll, a driving member in the form of a belt drive surface is employed. For instance, in the treatment of nonwovens and papers, large endless belts having belt widths greater than five feet are feasible. The belts may have appropriate gripping or driving surfaces. The material is confined against either the flat or the curved portion of the belt. For obtaining angular treatment a retarder set at an angle to the direction of travel can be employed in the flat portion of the belt, with considerable simplicity. FIG. 12 illustrates this arrangement when the development of the drive surface is taken as the belt here being discussed.

The retarder as described above can be employed to retard materials driven on other surfaces, such as for instance paper being driven and creped on the conventional hot surface of a Yankee Dryer.

From the foregoing description of preferred embodiments of the invention it is apparent that there are a host of variables which affect the specific structure and geometry to be employed for treating any given material for the purpose of producing any specific desired effect in the end porduct. For example, the drive surface may vary from smooth to very rough, the particular character thereof being chosen depending on the nature of the material being run and the desired end result. The drive surface geometry may vary from flat to sharply curved, depending on whether it is provided by a belt or rolls of different diameters. The various parts of the machine which engage the material may be heated to any desired temperature for the treatment contemplated, but the heat applied to the material is not only a function of temperature but the time of exposure of the material to the heated elements and this in turn is a function of machine speed. This fact creates start-up and stopping problems where higher temperatures are employed, even though the temperatures are satisfactory under running conditions. It will be understood that these are but a few examples of the many variables (at least 50) which we have identified and which include: the characteristics of the drive surface, of the confining surface and of the retarding surface, the dimensions and mutual spacings thereof, the innumerable kinds of materials which may be treated, and the profound differences between starting and running conditions.

What is claimed is:

1. In a machine capable of treating a traveling length of flexible material, the combination, in the running condition of the machine, comprising:

a drive member providing a movable drive surface for contacting one side of the material,

means providing a confining surface and a retarding surface,

said last named two surfaces being arranged for contacting the other side of the material and being in immediate succession and opposite and spaced from said drive surface,

said drive surface and said confining surface together defining a first passage for said material,

means for pressing the means defining said confining surface tightly against said material at a point within but near the end of said first passage so as to press said material in untreated condition into driven engagement with said drive surface along a line and propel it forwardly within said first passage in slipping engagement with said confining surface,

said drive surface and said retarding surface defining together a second passage, immediately following said first passage, into which said material may enter from said first passage, said retarding surface and said drive surface being so mutually spaced at least at the entrance portion of said second passage that said material will enter therein and pass therethrough essentially without changing its path of travel and therein engage and be retarded by said retarding surface,

said retarding surface having a multiplicity of projecting portions operable successively to grip and release the material thereby to locally retard the material as it passes through said second passage to exert sufficient retarding force thereon to cause a continuously replenished column of at least partially treated material to build up,

said retarding surface being essentially nonextensible and immobile in the direction of travel of the material,

said first passage having at least near its exit a dimension in the direction of the thickness of the material which is no greater than any similar significant dimension of said second passage,

whereby untreated material driven forward by said drive surface beneath said confining member will continuously impinge upon said column, the point of impingement comprising a treatment point, said treatment point being located in a zone defined by the exit portion of said first passage and the initial portion of said second passage,

the mutual spacing of said drive and confining surfaces and that of said drive and retarding surfaces and their frictional surface characteristics being so related to the retarding characteristics of said retarding surface that at said treatment point the forwardly propelled material supported by said surfaces has sufficient columnar strength to extrude said column of treated material from the passage portions in which it is contained.

2. The machine of claim **1** including a resilient means supporting said retarding surface in the direction of the thickness of the material being treated.

3. The machine of claim **1** wherein said projecting portions comprise projections formed of hard grit grains bonded to a non-extensible backing sheet.

4. The machine of claim **1** wherein all portions of said retarding surface which engage said material are spaced at least as far from said drive surface as the portion of said retarding surface which first effectively retards said material.

5. The machine of claim **1** wherein said drive surface comprises a surface having ridges and grooves, the grooves having a component in the direction of travel of the material, said grooves at said treatment point providing spaces in which the material may initially slide backward relative to said drive surface and compress before leaving said grooves.

6. The machine of claim **1** wherein said drive surface is of cylindrical form and said retarding surface commences less than 10 arc degrees from said treatment point.

7. The machine of claim **1** wherein the means defining said retarding surface comprises a fabric.

8. The machine of claim **1** wherein the means providing said retarding surface is a layer member, said drive surface is curved and a bent metal member lies over said layer member positioning said retarding surface with respect to said drive surface.

9. The machine of claim **8** wherein a backing layer of resilient material lies over said retarder layer member and said bent metal member comprises a sheet form metal keeper member over said backing layer.

10. The machine of claim **1** wherein said retarding surface is provided by a sheet form member and wherein said pressing means lies above the region of the exit portion of said first passage, said pressing means being adjustable relative to said sheet form member backwardly and forwardly in the direction of travel of the material so as to vary the proportion of force it applies upon said confining surface and upon said retarding surface.

11. The machine of claim **1** wherein said confining surface is provided by a primary member comprising a sheet of deformation-resistant metal, the body thereof having a first thickness and tapering to a reduced thickness at the exit of said first passage, said retarding surface being provided by a retarder member overlying said primary member at least in part.

12. The machine of claim **1** wherein said retarding surface is backed by a layer of a material deformable in the direction of the thickness of said flexible material being treated, extending over said confining surface and deformed about the trailing edge of the means defining said confining surface to position said retarding surface with respect to said drive surface.

13. The machine of claim **12** including an outer sheet form member of deformation resistant and force-transmitting material overlying said layer, and a presser having a narrow pressing surface engageable with said outer member in a position to transmit pressing forces to a predetermined region beneath said confining surface through the thickness of the intervening members, said presser including mechanism for adjusting the position of engagement of said presser with said outer member in the direction of travel of said material.

14. The machine of claim **1** wherein there is provided an abrupt enlargement in the direction of the thickness of the material of the spacing between said retarding surface and said drive surface immediately beyond the exit of said first passage to permit creping of the overall sheet of the material, the machine being capable of producing a time-varying densification of the material as the resistance of the column of compressed material varies with the varying stages of crepe formation.

15. The machine of claim **1** wherein said treatment point is located in said first passage and said first passage beyond said treatment point is enlarged in the direction of the thickness of the material to permit creping of the overall sheet of the material, the machine being thereby capable of producing a time-varying densification of the material under said confining surface as the resistance of the column of compressed material varies with the varying stages of crepe formation.

16. The machine of claim **15** wherein there is provided an abrupt enlargement in the direction of the thickness of the material of the spacing between said retarding surface and said drive surface immediately beyond the exit of said first passage to assist the aforementioned time-varying densification of the material.

17. The machine of claim **15** wherein the surface defining the enlarged portion of said first passage is continuous with said confining surface.

18. The machine of claim **15** wherein, at least immediately preceding said retarding surface, the spacing of the surfaces defining the enlarged portion of said first passage is substantially greater than the spacing of said confining surface from said drive surface in the region immediately preceding said point of treatment, enabling expansion of the material in the direction of its thickness before reaching said retarding surface.

19. The machine of claim **15** wherein within said first passage the spacing of said confining surface from said drive surface abruptly increases and extends increased to said retarding surface.

20. The machine of claim **19** wherein said confining surface is provided by more than one member in overlapped relation.

21. A method of treating a traveling length of flexible material comprising:

providing a movable drive surface for contacting one side of the material,

providing a confining surface and a retarding surface arranged for contacting the other side of the material and being in immediate succession and opposite and spaced from said drive surface, said retarding surface having a multiplicity of projecting portions and being essentially non-extensible and immobile in the direction of material travel,

said drive surface and said confining surface together defining a first passage for said material,

pressing said material in untreated condition into driven engagement with said drive surface at a point in the exit portion of said first passage to propel it forwardly within said first passage in slipping engagement with said confining surface,

said drive surface and said retarding surface defining together a second passage immediately following said first passage, said retarding surface and said drive surface being so mutually spaced at least at the entrance portion of said second passage that said material will enter therein and pass therethrough essentially without changing its path of travel,

in said second passage successively gripping and releasing said material by means of said projecting portions thereby locally retarding said material as it passes through said second passage to cause a continuously replenished column of at least partially treated material to build up,

said first passage having at least near its exit a dimension in the direction of the thickness of the material which is no greater than any similar significant dimension of said second passage,

whereby untreated material driven forward by said drive surface beneath said confining member will continuously impinge upon said column, the point of impingement comprising a treatment point, said treatment point being located in a zone defined by the exit portion of said first passage and the initial portion of said second passage,

the mutual spacing of said drive and confining surfaces and that of said drive and retarding surfaces and their frictional surface characteristics being so related to the retarding characteristics of said retarding surface that at said treatment point the forwardly propelled material supported by said surfaces has sufficient columnar strength to extrude said column of treated material from the passage portions in which it is contained.

22. The method of claim **21** employed in treating textiles wherein said retarding surface is arranged to nap the surface of the material in the process of retarding it.

23. The method of claim **21** including slidably confining said material substantially to its original thickness at said treatment point and releasing said compressed material to expand its thickness at a point spaced downstream of said treatment point.

24. The method of claim **21** including slidably confining said material following said treatment point at a spacing greater than the respective spacing at said point of treatment with a low friction confining surface prior to exposing said material to said retarding surface.

25. The method of claim **21** for bulking or softening a length of fibrous material wherein said drive surface is provided with material gripping projections and said material is slippably confined against said drive surface and at least portions thereof pressed into the intervals between said projections by said confining surface, and including the step of maintaining the relationship of the surfaces such that the drive surface slides with respect to the material so that the projections tend to pull fibers at one side of the material forwardly and out of said intervals while the retarding surface has a relatively opposite effect on fibers at the other side of the material.

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