Jan. 2, 1962

E. COHN ET AL

3,015,145

METHOD AND APPARATUS FOR TREATING
WEB MATERIALS, SUCH AS FABRICS

Filed Feb. 4, 1957

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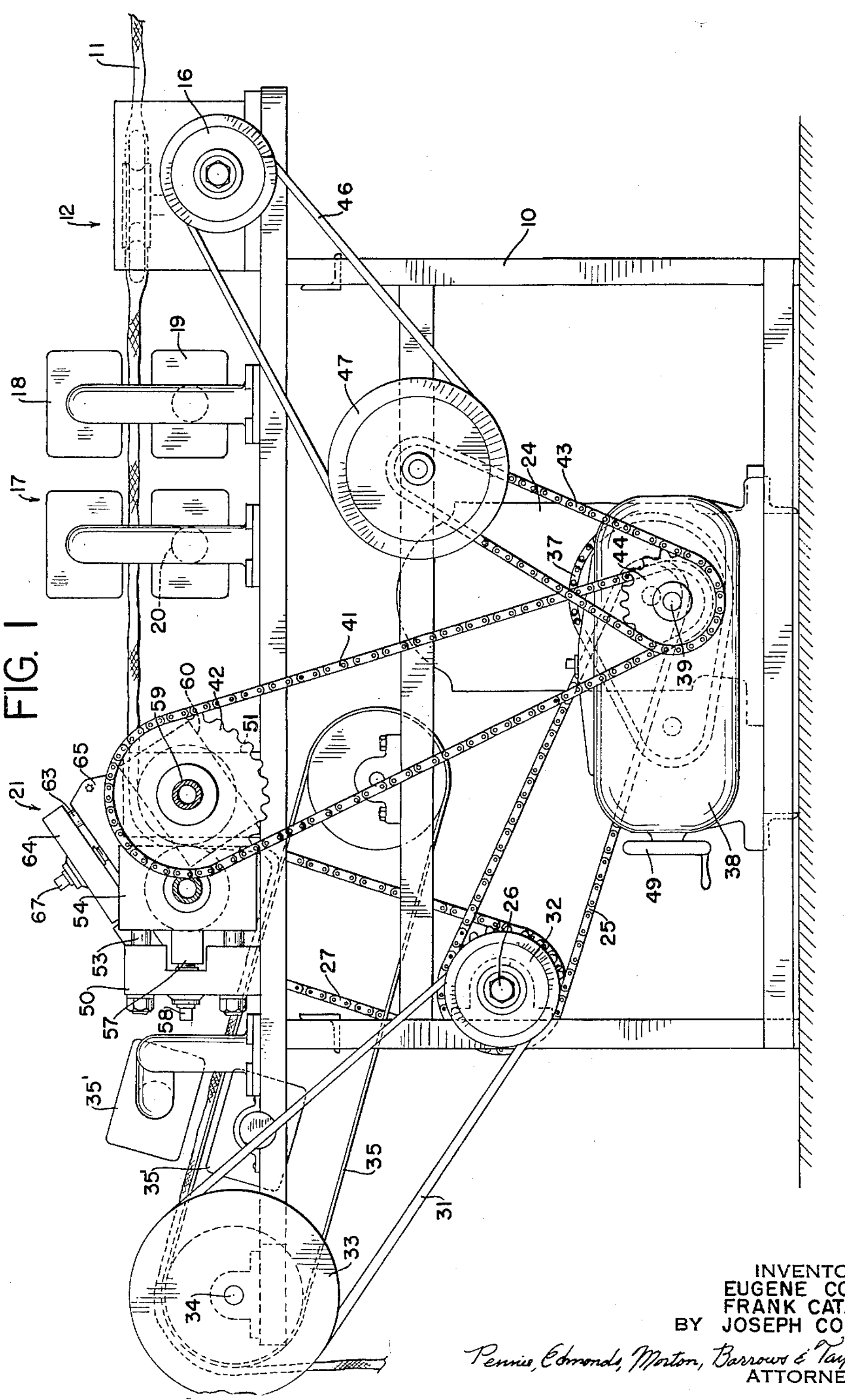

FIG. 1

INVENTORS
EUGENE COHN
FRANK CATALLO
BY JOSEPH COHN

Pennie, Edmonds, Morton, Barrows & Taylor
ATTORNEYS

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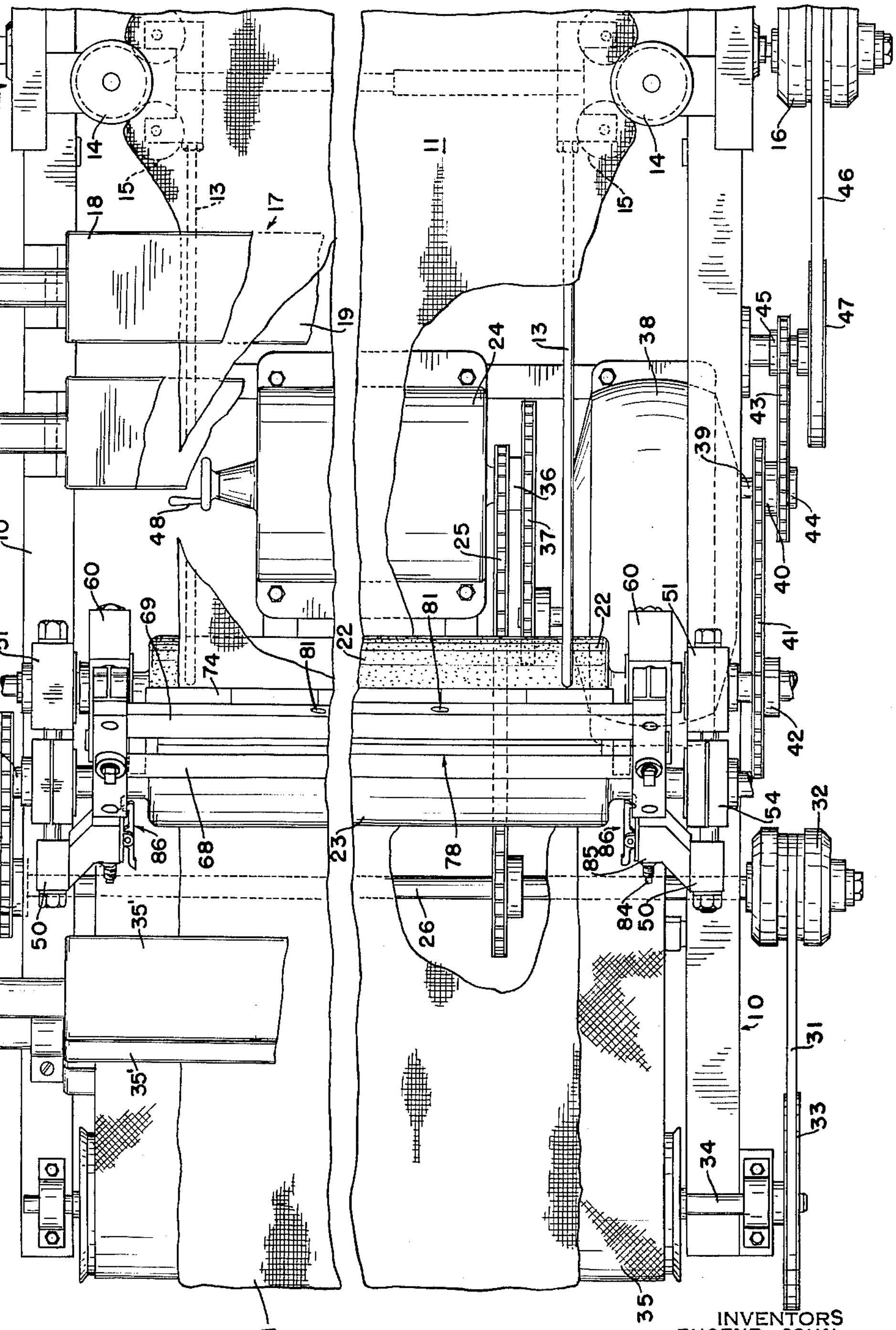


FIG. 2

INVENTORS
EUGENE COHN
FRANK CATALLO
JOSEPH COHN

BY Pennie, Edmonds, Morton, Barrows & Taylor
ATTORNEYS

FIG. 3

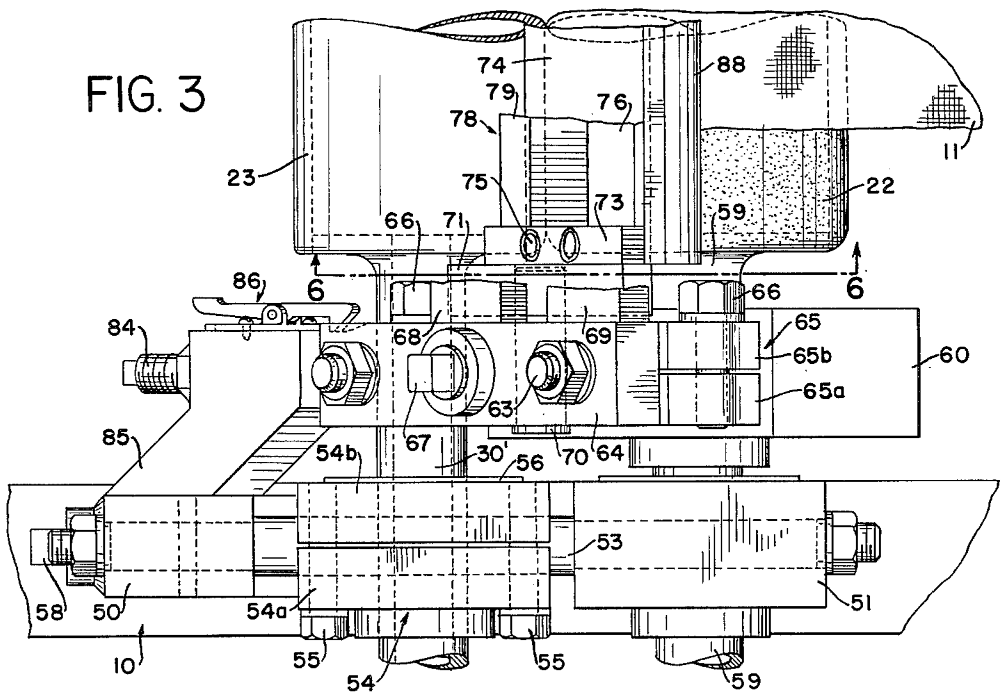
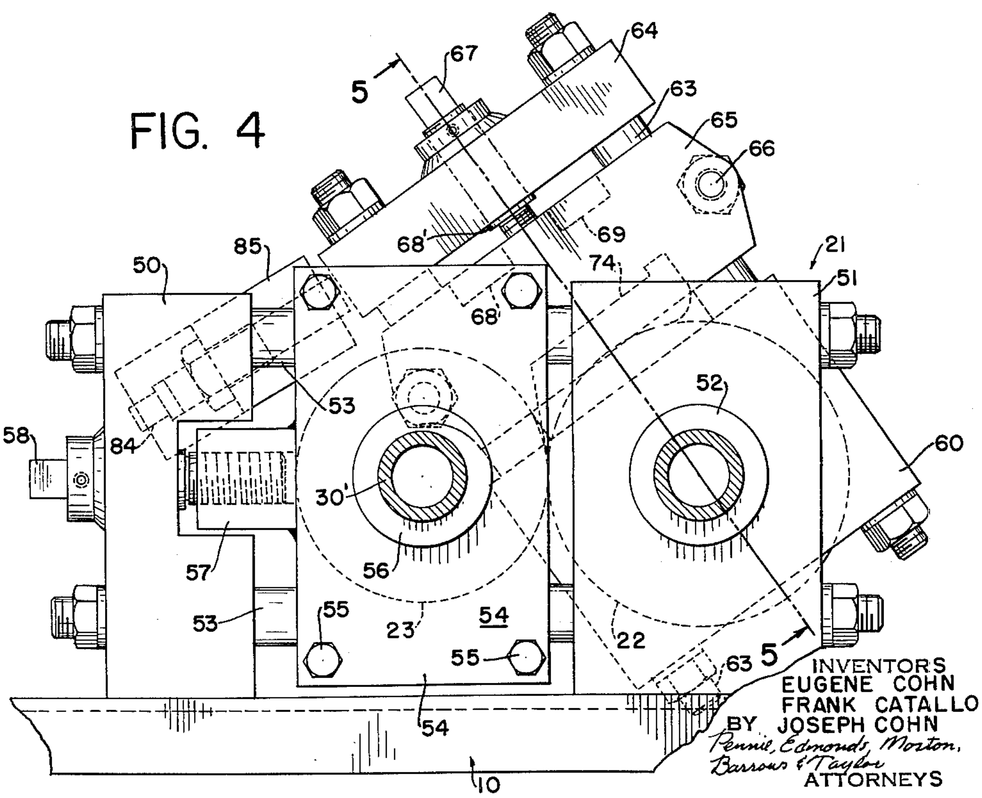


FIG. 4



INVENTORS
EUGENE COHN
FRANK CATALLO
BY JOSEPH COHN
Pennie, Edmonds, Morton, Barrows & Taylor
ATTORNEYS

FIG. 5

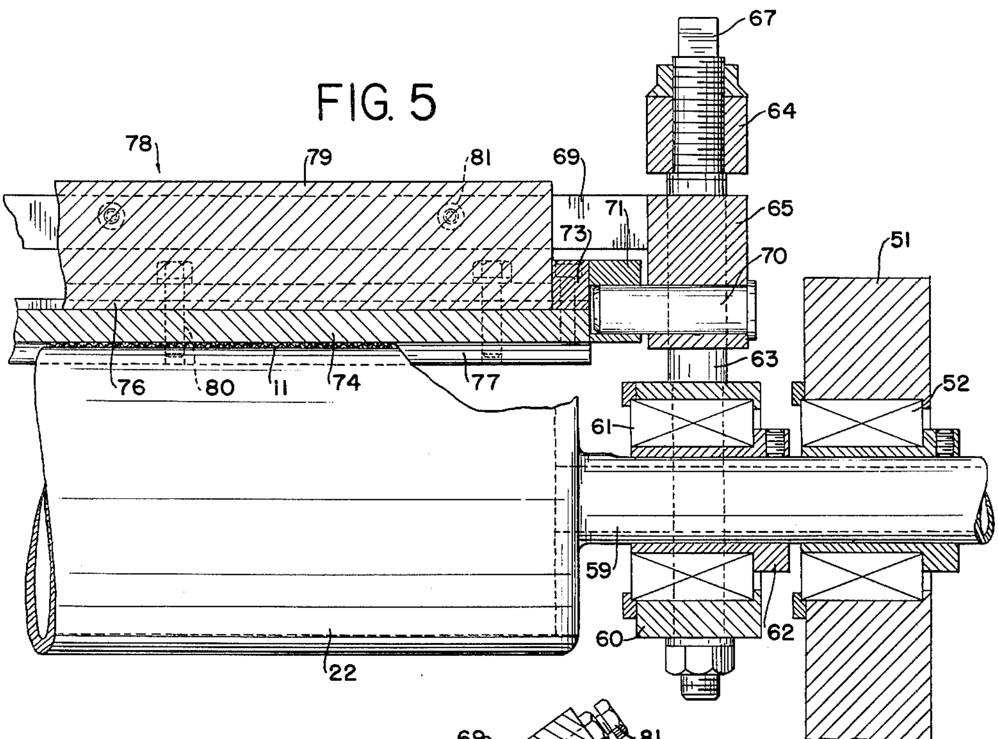
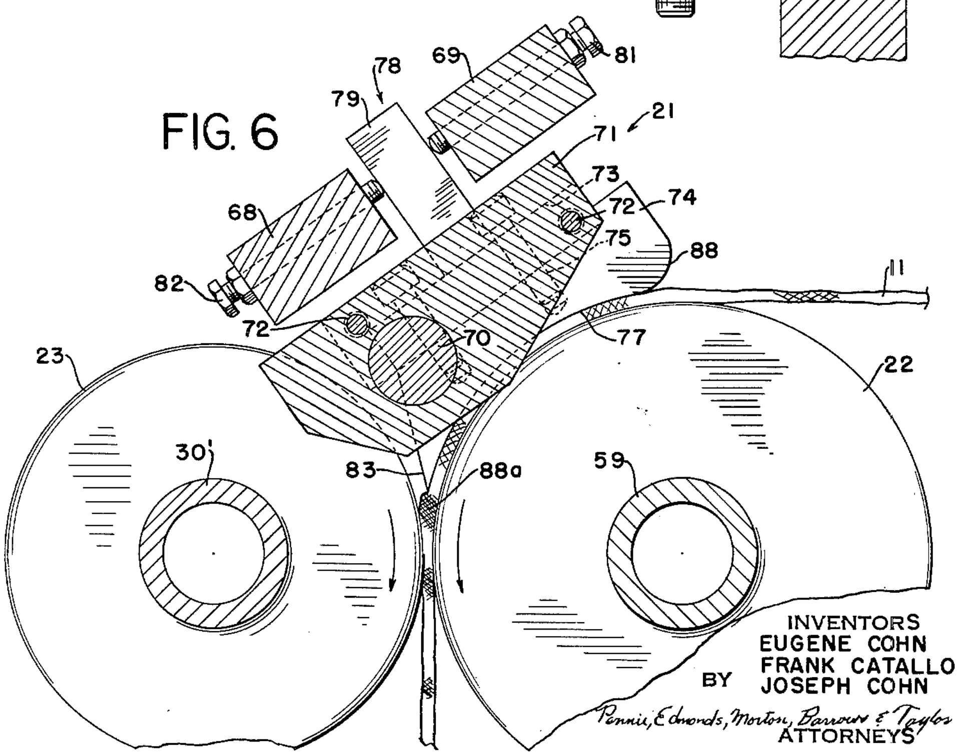


FIG. 6



INVENTORS
EUGENE COHN
FRANK CATALLO
JOSEPH COHN
BY
Pennie, Edmonds, Morton, Barrows & Taylor
ATTORNEYS

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FIG. 9

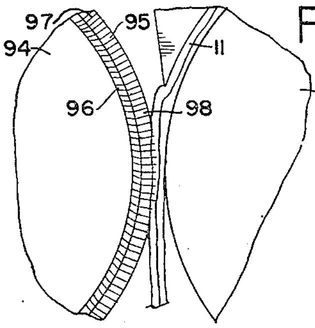


FIG. 7

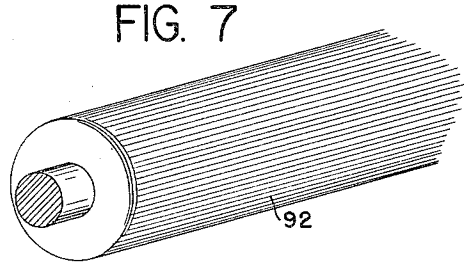


FIG. 8

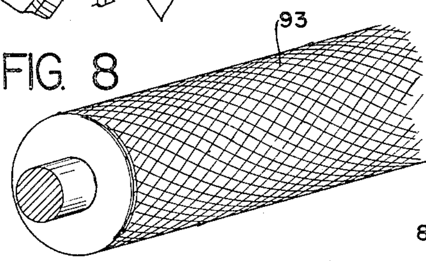


FIG. 10

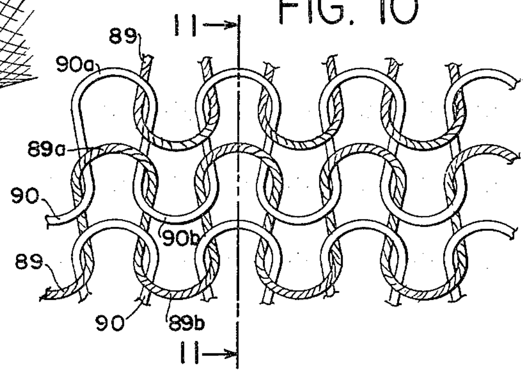


FIG. 11

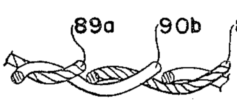


FIG. 12

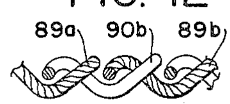


FIG. 13

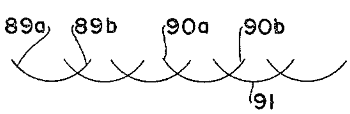


FIG. 14

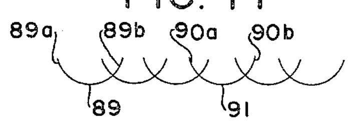


FIG. 15

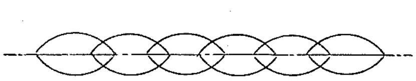
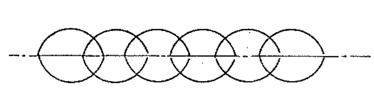


FIG. 16



INVENTORS
EUGENE COHN
FRANK CATALLO
BY JOSEPH COHN
Pennie, Edmonds, Morton, Barrows & Taylor
ATTORNEYS

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METHOD AND APPARATUS FOR TREATING WEB MATERIALS, SUCH AS FABRICS

Eugene Cohn, Great Neck, Frank Catallo, Elmont, and Joseph Cohn, New York, N.Y., assignors to Compax Corp., Woodside, N.Y., a corporation of New York

Filed Feb. 4, 1957, Ser. No. 638,154
8 Claims. (Cl. 26—18.6)

This invention relates generally to the treatment of fabrics, and more particularly to an improved method and apparatus for pre-shrinking various fabrics. The invention is particularly applicable to the mechanical pre-shrinking of tubular knitted material; but may also be advantageously employed in connection with the pre-shrinking of other materials, such as non-tubular knit fabrics and various woven fabrics.

Pre-shrinkage of fabrics has been a problem in the industry for many years. A wide variety of techniques and mechanisms have been proposed for carrying out mechanical pre-shrinking or compacting on a large-scale commercial basis. However, insofar as we are aware, the various arrangements heretofore known in the industry have been either unsatisfactory for one reason or another for commercial use or have been limited as to the extent of shrinkage produced or the variety of materials upon which they may effectively be employed. Thus, at the present time, no entirely satisfactory, versatile mechanical pre-shrinking methods or apparatus have met with widespread acceptance in the industry.

One of the recent improvements in the art of mechanical pre-shrinking is based on the so-called column theory, and involves the application, in a continuous process, of compressive forces to short columnar lengths of material. The application of such compressive stresses to unsupported columnar lengths of material operates, with some fabrics, to effect permanent shortening of the material. The foregoing method and one form of apparatus for carrying out the method are described and claimed in United States Patents No. 2,765,513 and No. 2,765,514, to Richard R. Walton.

The columnar theory of mechanical pre-shrinkage appears to give generally satisfactory results in the case of woven fabrics where at least the warp threads or yarns are disposed generally in the direction of application of the compressive compacting forces, and the yarns themselves may constitute individual columns which can be subjected to longitudinal compressive stresses to the extent required for acceptable compacting or pre-shrinking. However, in knit fabrics, the individual threads or yarns are disposed in more or less zig-zag fashion, or, more accurately, in a series of loops progressing transversely of the fabric. Accordingly, it is difficult if not impossible to apply columnar compression strains to the individual threads or yarns making up a length of knitted fabric. The dimensional limitations of a mechanical compacting apparatus are such that the so-called columnar length of fabric necessarily includes a plurality of "rows" of loops, and when compressive forces are applied to the columnar length the rows of loops or the individual loops bend or slide with respect to each other, or both, so that little effective columnar stressing takes place.

In accordance with the invention, material such as knitted fabric may be mechanically compacted or pre-shrunk with effectiveness and to a high degree by an improved method which is outwardly related to the so-called columnar compression method, but which constitutes a substantial improvement thereover, to the end that almost any type of fabric, including tubular knitted fabric, may be effectively compacted in a rapid and continuous operation and in such a manner as to permit advantageous incorporation in commercial operations.

Although we do not wish to limit this invention to a particular theory or explanation of fabric behavior, it is our belief that in the new compacting method successive incremental lengths of fabric are shortened not by columnar compression in the threads or yarns, but by relative sliding of the knit loops and buckling or bunching of the yarns in a direction generally transverse of the plane of the material. The new method thus involves the application of compressive forces to successive, advantageously heated, incremental lengths of material, whereby to effect a buckling and/or sliding together of the yarns and a relieving of stresses therein. These incremental lengths are then subjected to transverse pressure whereby a mechanical setting of the rows of loops, individual loops and the yarns therein in such condition may be effected in an operation akin to ironing.

With particular regard to the compacting of knitted material, the application of longitudinal compressive forces to successive incremental lengths of the fabric is thought, in part at least, to produce a result which, by analogy, is similar to sliding rows of fish scales one upon the other. Thus, in a plain knitted fabric, for example, the individual yarns are looped back and forth, the individual loops being disposed in generally longitudinal relation to the fabric, while the individual threads or yarns progress generally transversely thereof. The individual loops are interlocked and lapped one upon the other. Accordingly, when longitudinal compressive forces are applied to longitudinal rows of lapped and interlocked knit loops, the individual loops slide upon each other, buckle, and tend in certain instances to up end, so that the length of the fabric is decreased while the thickness thereof is increased. At the same time it is believed that much of the residual stress, from prior processing, in the loops and yarn thereof is relieved. In accordance with the method of the invention, the compacted or compressed and probably stress-relieved loops are ironed in place, while maintained under compression, so that the various yarns are set in their deformed and probably stress-relieved condition with sufficient permanence for acceptable commercial use.

In general, the method of the invention involves the continuous feeding of a length of material between the nip of a pair of rolls rotating at different speeds. The slower of the two rolls is referred to as a retarding roll, and determines the speed at which the material leaves the roll nip. The faster one of the rolls is the feeding roll, and determines the speed at which the fabric is fed toward the roll nip. The fabric is frictionally engaged by the feeding roll up to a point spaced a short distance from the roll nip, and the fabric is caused to decelerate and compact immediately before entering the roll nip. In accordance with the invention, the rolls are heated sufficiently to set the deformations of the compacted material, as the material passes through the roll nip, whereby the fabric emerges from the roll nip in a pre-shrunk condition.

One of the important features of the invention resides in the provision of improved arrangements for handling the feeding and retarding of the fabric or material whereby various materials, including tubular knitted fabrics, may be processed in an effective manner. As will be understood, tubular knitted material is manufactured in the form of continuous, seamless tubes, which, when folded flat, form double layers of material. Heretofore, tubular knitted material has been difficult if not impossible to mechanically compact because of the delamination or shifting of one of the layers of the doubled material with respect to the other. In the new method, however, the handling of the material during feeding and retarding is such that delamination of the material is avoided and both layers of the doubled material are acted upon with equal effectiveness.

Another feature of great importance resides in the provision of new methods and apparatus for effectively compacting material in its dry form. Thus, in most heretofore known mechanical compacting methods, it is usually necessary, or at least highly desirable, to moisten or wet the material before subjecting it to compacting operations. This necessitates the subsequent drying of the material, involving additional expense and bulky drying equipment. In the new method, the residual moisture in the "dry" material (approximately 4 to 6 percent) is adequate for effective compacting. It should be understood, however, that moisture may be added to the fabric, if desired, within the contemplated scope of this invention, even though such addition of moisture is generally neither necessary nor desirable.

Another advantageous feature of the invention resides in the provision of a new method and apparatus for compacting fabric materials, in which the power required for compacting is extremely low, as compared with prior compacting techniques. Thus, in most compacting arrangements of a similar nature, it is necessary to employ deformable elements, such as rubber belts or rubber-covered rolls. A large part of the power required to carry out the compacting operation is expended in the deformation of such elements, as by stretching or compressing. Accordingly, not only are the power requirements unnecessarily high, but it is usually necessary to replace the deformable elements frequently. On the other hand, the method and apparatus of the present invention employ no deformable elements, and the greater part of the power required to carry out the process is actually usefully applied to the textile material.

The apparatus for carrying out the new method is of a generally simplified nature throughout, is physically compact, and is designed for long periods of maintenance-free operation. One of the specific improved features of the apparatus resides in the provision of novel arrangements for feeding and retarding tubular material in flat, double-layer form, without delaminating the material or causing the material to be permanently marked or otherwise undesirably deformed.

For a better understanding of the invention, reference should be made to the following detailed description and to the accompanying drawings, in which:

FIG. 1 is a side elevation of an apparatus constructed in accordance with the invention for mechanically compacting fabrics in accordance with the new method;

FIG. 2 is a top plan view, with parts broken away, of the apparatus of FIG. 1;

FIG. 3 is an enlarged fragmentary top plan view of the compacting rolls incorporated in the machine of FIG. 1, illustrating arrangements for mounting and adjusting the rolls;

FIG. 4 is an enlarged fragmentary end view of the roll assembly of FIG. 3;

FIG. 5 is an enlarged fragmentary cross-sectional view, with parts broken away, taken generally along line 5—5 of FIG. 4;

FIG. 6 is an enlarged fragmentary cross-sectional view taken generally along line 6—6 of FIG. 3;

FIGS. 7 and 8 are fragmentary perspective views of two types of fabric feeding rolls which may be incorporated in the apparatus of FIG. 1;

FIG. 9 is an enlarged fragmentary cross-sectional view illustrating one contemplated type of retarding roll which may be incorporated in the machine of FIG. 1;

FIG. 10 is a greatly enlarged fragmentary representation of a plain knitted fabric, illustrating generally the arrangement of the individual threads or yarns thereof, the fabric being illustrated with the so-called "rough" side thereof facing upwardly;

FIG. 11 is a cross-sectional representation of the fabric shown in FIG. 10, taken along line 11—11 thereof;

FIG. 12 is a cross-sectional view similar to FIG. 11 representing the fabric of FIG. 10 after compacting;

FIGS. 13 and 14 are diagrammatic representations of the fabric cross-sections of FIGS. 11, 12, respectively; and

FIGS. 15 and 16 are diagrammatic cross-sectional representations of a plain knit tubular fabric before and after compacting.

Referring now to the drawing, and initially to FIGS. 1 and 2 thereof, the reference numeral 10 designates a frame structure of more or less conventional form which supports the active components of the compacting apparatus. Adjacent one end of the frame 10 is a suitable means (not shown) for holding a supply of material which, in this illustration, is a length of tubular knitted material 11.

At the entry end of the frame 10 is mounted a fabric propelling or guiding mechanism, generally designated by the numeral 12, which draws the material 11 (if a propeller as well as a guiding means) from the supply means and opens, flattens, aligns, and supports the material above the frame 10. The propeller, which does not itself constitute part of the present invention, may comprise a pair of spaced bars 13 (FIG. 2) supported interiorally of the tubular material and extending forwardly above the frame 10 to hold the material 11 in a flat condition. Or if desired, the propeller may be of the belt type as disclosed, for example, in Cohn et al. Patent No. 2,589,344 assigned to the same assignee as is this application. Any feeding or guiding device may, in fact, be employed provided it effects a presentation of (feeds in the case of a propeller) the fabric to the compactor in open, flat, and substantially wrinkle-free condition. Adjacent the mounted ends of the bars 13 are opposed sets of rollers 14, 15 which grip the edges of the material and feed it over the propeller or spreader. The outer rolls 14 are driven through mechanism including a pulley 16 and serve in cooperation with rollers 15 to draw the material from the supply means.

Mounted on the frame 10, adjacent the exit end of the propeller, is a steaming station 17 comprising one or more pairs of steam boxes 18, 19 disposed on opposite sides of the plane of the fabric 11 and supplied with steam through ducts 20. The steaming station 17 forms no part of the present invention and may be eliminated entirely in most cases. However, the steaming station may be useful in compacting operations in which it is desirable to moisten and/or calender the fabric prior to compacting (in the latter case a pair of calendering rolls could be mounted to press the fabric after it leaves the propeller or guiding means). For example, we have found that in treating tubular knit fabric of certain stitch construction, the addition of a small amount of moisture, by steaming or otherwise, will assist in preventing delamination of the layers of the flattened fabric in the compacting apparatus.

Spaced forwardly of the steaming station 17, in the direction of movement of the fabric 11, is a compacting station 21, to be described in considerable detail, which comprises spaced opposed rolls 22, 23 which are advantageously formed of a substantially non-resilient, heat conductive material such as steel. The axes of the rolls 22, 23 are advantageously disposed in a common horizontal plane, whereby the rolls form a nip through which the fabric 11 may pass vertically downward. As will be described in greater detail, the rolls 22, 23 are rotated at different speeds, and to this end separate driving means are provided for the rolls. Thus, enclosed generally within the limits of the frame 10 is a motor driven variable speed transmission mechanism 24 which operates through a chain 25 and suitable sprockets to drive a shaft 26 journaled in the frame 10. One end of the shaft 26 is connected by means of a chain 27 and sprockets 28, 29 to a shaft or neck portion 30 of the roll 23, which may be considered the retarding roll of the compacting station.

The opposite end of the shaft 26 is connected by means of a belt 31 and pulleys 32, 33 to a shaft 34 driving a suitable conveyor belt or wire 35. The retarding roll 23 and conveyor wire 35, being driven from a common shaft 26, operate in fixed relation to each other and, advantageously, the speed of movement of conveyor wire 35 should be approximately the same as the peripheral speed of the retarding roll 23. As shown in FIG. 1 the textile material 11 passing downwardly between the rolls 22, 23 falls upon the forwardly moving upper surface of the conveyor wire 35 and is conveyed away to a suitable fabric receiving means (not shown). If desired, a second pair of steam boxes 35' similar to steam boxes 18, 19, may be employed to steam the compacted fabric on conveyor 35.

The output shaft 36 of the motor driven variable speed transmission 24 is also connected by means of a chain 37 and suitable sprockets to the input of a second variable speed transmission, such as a conventional P.I.V. drive unit 38. The output shaft 39 of the P.I.V. unit 38 mounts a sprocket 40 which drives through a chain 41 and sprocket 42, the roll 22, which may be considered the feeding roll of the compacting station 21. The output shaft 39 of the P.I.V. unit is also connected through a mechanism including chain 43, sprockets 44, 45, belt 46 and pulleys 47 and 16, to the rolls 14, 15. Thus, the feeding roll 22 and the rolls 14, 15 operate in fixed relation to each other, and, advantageously, the arrangement is such that the rolls 14, 15 draw material onto the guide bars 13 at the same rate the feeding roll 22 carries the fabric into the nip of rolls 22, 23.

In the illustrated form of the invention, the speed of operation of the apparatus as a whole may be varied by appropriate adjustment of the motor driven variable speed transmission 24, such adjustment being effected by means of a suitable adjusting wheel 48. This will determine the rate at which the fabric is fed into the compacting station 21. The speed of operation of the retarding roll 23 and conveying wire 35 may be adjusted with respect to the speed of the fabric feeding rolls by adjustment of the P.I.V. drive unit 38, such adjustment being effected by means such as hand wheel 49.

Referring more specifically now to FIGS. 3–6, it will be observed that the compacting station 21 comprises pairs of blocks 50, 51 mounted rigidly on the frame 10 in upstanding relation. The blocks 50, 51 are spaced longitudinally on the frame, and sets of the blocks are mounted at opposite sides of the frame. Blocks 51 constitute journal members, and have bearing means 52 therein for rotatably mounting the feeding roll 22.

Extending between the blocks 50, 51 of each pair are vertically spaced, longitudinally disposed guide rods 53, bolted securely in place in the blocks. The guide rods 53 slidably mount bearing blocks 54, each consisting of two parts, 54*a*, 54*b* (FIG. 3) secured together by means of bolts 55. The blocks 54 receive suitable bearing means 56 for journaling shaft portions 30, 30' of the retarding roll 23. Preferably, although not necessary, the rolls 22, 23 are journaled for rotation about horizontal axes disposed in the same horizontal plane.

As shown best in FIG. 4, the movable bearing blocks 54 are provided at one side with internally threaded bosses 57 which receive the threaded ends of adjusting screws 58. The adjusting screws 58 are rotatable in the blocks 50, while being locked against axial movement therein so that upon rotation of the screws, bearing blocks 54 are moved longitudinally along the guide rods 53 to carry the retarding roll 23 toward or away from the feeding roll 22. In the illustrated form of the invention, the bearing blocks 54 are separately adjustable at opposite sides of the machine frame. However, it will be understood that interconnected adjusting means may be provided wherever desirable or expedient.

Mounted on shaft portions 59 of the feeding roll 22, at opposite ends thereof, are bearing blocks 60. The bearing blocks 60 have suitable bearings 61 therein, engaging the shaft portion 59 to facilitate relative rotation between the shaft portions and the bearing blocks. Suitable collars 62 which are parts of the bearing inner races are fixed to the shaft portions 59 to locate the blocks 60 properly on the shaft portions. The blocks 60, which may be considered supporting blocks, rigidly mount pairs of spaced parallel guide rods 63. At their upper ends, the guide rods 63 are rigidly secured to tie bars 64 which are spaced several inches away from the support blocks 60.

Movably mounted on the pairs of guide rods 63 are slide blocks 65 clamped on guide rods by means of bolts 66. As shown in FIG. 4 the slide clocks 65 are threadably engaged by rotatable adjustment screws 67 passing through bushings 68' in the tie bars 64. Accordingly, by rotation of the adjusting screws 67 the slide blocks 65 may be caused to move on the guide rods 63 toward and away from the axis of the feeding roll 22. In this respect, it will be observed in FIG. 4 that the guide rods 63 are disposed on opposite sides of the axis of feeding roll 22 in parallel relation to an imaginary axis extending radially from the roll axis.

Rigidly secured at their opposite ends to the inner parts 65*b* of the slide blocks 65 are spaced parallel cross bars 68, 69. The cross bars are of slightly greater length than the large diameter portions of the feeding and retarding rolls 22, 23, as shown in FIG. 2, and are disposed between the guide rods 63, in generally symmetrical relation thereto. In the assembled apparatus the slide blocks 65 and cross bars 68, 69 constitute a unitary structure.

Mounted on the slide blocks 65, and projecting inwardly thereof, are pivot pins 70, shown best in FIGS. 5 and 6. The pivot pins 70, at opposite sides of the machine, are aligned on a common axis and pivotally support pivot blocks 71. Secured to the inner faces of pivot blocks 71, by means of suitable bolts 72, are cleats 73 which, in turn, rigidly mount an arcuate shoe 74, by means of bolts 75 extending through the cleats and through a sole plate 76.

In accordance with the invention, the shoe 74 has an arcuate lower surface 77 (see FIG. 6) which conforms generally with the cylindrical surface of the feeding roll 22 over a substantial arc of, for example 60 degrees. Advantageously, the arcuate surface 77 of the shoe 74 is concentric, over its arc, with the surface of the feeding roll 22; and, while the concentric relationship of these surfaces depends on the radial spacing therebetween, which is adjustable, it is entirely satisfactory to provide for exact concentricity of the surfaces at an average adjusted position of the shoe 74, allowing for relatively negligible variations from exact concentricity as the shoe is adjusted throughout its normal range of a relatively few thousandths of an inch.

As shown in FIG. 2, the shoe 74 extends along the entire length of the feeding roll 22 while being supported only at its ends by means of the cleats 73. Accordingly, to stiffen the shoe 74, as well as to provide for certain adjustments thereof, a T-bar 78, comprising the sole plate 76 and an upright web plate 79 is secured to the upper surface of the shoe 74, by means of spaced bolts 80. The upright web 79 of the T-bar 78 imparts substantial stiffness to the shoe 74 to prevent the shoe from sagging in its center portion. Moreover, as shown best in FIGS. 5 and 6, the web plate 79 projects upwardly between the cross-bars 68, 69 and is held in a desired position between the cross-bars by means of a plurality of sets of opposed adjusting screws 81, 82. By appropriate manipulating the adjusting screws 81, 82 the assembly including the T-bar 78, shoe 74, cleats 73 and pivot blocks 71 may be pivoted about the axis of the pivot pins 70. By this means, the shoe 74 may be adjusted into the desired concentric relation to the feeding roll 22.

As shown in FIG. 6, the shoe 74 has a lower terminating edge 83 in the form of a relatively sharp, almost knife-like edge. The dimensions and configuration of the edge 83 of the shoe are not, in themselves, critical.

However, they should be so related to the curvature and spacing between the feeding and retarding rolls 22, 23 that the shoe may be inserted between the rolls to a point where the terminating edge 83 is spaced about a quarter of an inch from the nip of the rolls, the nip being considered for this purpose to lie in the plane containing the axes of the respective rolls 22, 23.

As will be apparent from the foregoing description, the entire assembly which mounts the shoe 74 is carried by the support blocks 60 journaled on shaft portions 59 of the feed roll 22. Accordingly, this entire assembly may be pivoted on the shaft portions 59 to carry the shoe 74 circumferentially about the feeding roll 22, without, however, altering any other aspect of adjustment of the shoe relative thereto. Thus, the spacing between the terminating edge 83 of the shoe and the nip of the rolls 22, 23 may be readily adjusted by pivoting the entire shoe mounting assembly about the shaft portions 59. To this end, adjusting screws 84 are threadedly received in outboard brackets 85 secured to the support blocks 50. As shown in FIG. 4, the adjusting screws 84 project upwardly and rearwardly from the brackets 85 and are adapted to engage the lower ends of the tie bars 64. When the shoe supporting assembly is tilted forwardly, as shown in FIG. 4, it will be drawn downwardly by gravity until the tie bars 64 engage the projecting ends of the adjusting screws 84. By backing off the screws 84, the terminating edge 83 of the shoe may be moved closer to the roll nip, whereas by extending the screws the edge 83 will be moved away from the nip.

In most cases, the weight of the shoe supporting assembly is sufficient, in itself, to hold the assembly in its forwardly tilted position. However, wherever necessary or expedient, an adjustable latch device, such as that shown at 86 in FIG. 3, may be provided to secure the assembly in its forwardly tilted position.

In accordance with the preferred form of the invention, the feeding and retarding rolls 22, 23 are of hollow construction, and have hollow shaft portions whereby steam or other heating medium may be passed into and/or through the rolls. Thus, steam may be admitted into one end of each roll from a suitable steam source, as indicated at 87 in FIG. 2. Suitable rotatable fluid joints (not shown) may be provided at the opposite ends of the rolls 22, 23 for effecting the admission of steam at one end and the removal of the steam or condensate or both from the other end.

In carrying out the method of the invention, a length of tubular fabric 11 is passed through the rolls 14, 15 and threaded over the propeller bars 13. The forward ends of bars 13 extend to points adjacent the feeding roll 22, to support and align the fabric 11 before it reaches the compacting station and to deliver it thereto in untwisted, wrinkle-free condition. As shown in FIG. 1, the plane of the fabric 11 is advantageously approximately tangent to the upper peripheral surface portion of the feeding roll 22, whereby as the fabric passes over the discharge end of the propeller or spreader it moves onto and is supported by the feeding roll 22. The fabric 11 then enters the arcuate space between the roll 22 and the curved surface 77 of the shoe 74. This arrangement is illustrated in FIG. 6, and it will be observed therein that the entry side of the shoe 74 has a curved edge portion 88 to facilitate entry of the fabric between the feeding roll and shoe.

Advantageously, the spacing between the shoe 74 and feeding roll 22 is substantially uniform, and the spacing is preferably somewhat less than the normal thickness of the fabric 11. It does not appear that the spacing between the shoe 74 and feeding roll 22 is particularly critical, with the limitation that the spacing should not be greater than the thickness of the fabric (doubled in the case of tubular fabric) to be passed therethrough, at least to any appreciable extent, so that as the fabric passes through the space it will be urged against the surface of the feeding roll 22 sufficiently to effect frictional driving engagement between the feeding roll and the fabric. On the other hand, the spacing should not be so small as to cause the fabric 11 to be pressed with substantial localized pressure against the surface of the feeding roll 22, as such pressure merely introduces excessive frictional power losses and causes unnecessary wear upon the fabric. Thus, in the treatment of a tubular knitted fabric having a fifteen-thousandths inch doubled thickness, the spacing between the shoe 74 and feeding roll 22 may advantageously be on the order of ten-thousandths inch. For best results, the arcuate inner surface 77 of the shoe 74 should be as smooth as possible.

When the shoe 74 is properly adjusted with respect to the feeding roll 22, the fabric 11 will be fed through the space between the shoe and roll at a rate equal to the peripheral speed of the feeding roll, the ideal condition being such that there is no slippage between the feeding roll and fabric throughout this area. As the fabric emerges past the terminating edge 83 of the shoe it travels through a short material compacting zone 88*a* on the order of one-quarter of an inch in length before passing through the nip of the feeding and retarding rolls 22, 23. The ends of the compacting zone 88*a* are defined, in part, by the terminating edge 83 and the roll nip, as will be observed in FIG. 6. Advantageously, the spacing between the rolls 22, 23 may be in the order of one-third the normal fabric thickness so that localized pressure is applied to the fabric as it passes therethrough.

In accordance with the invention, the retarding roll 23 has a slower peripheral speed than the feeding roll 22, and the surface of the retarding roll is relatively rough and is such that the retarding roll has relatively high frictional gripping characteristics with the material which therefore assumes the peripheral speed of the retarding roll. The surface of the feeding roll 22 has relatively low frictional gripping characteristics with the material so that as the material assumes the peripheral speed of the retarding roll, at the roll nip, relative movement may take place between the contacting surfaces of the feeding roll and material, without adverse effect on the fabric.

Since the fabric 11 is being delivered or fed into the space below the terminating shoe edge 83 at a rate equal to the peripheral speed of the feeding roll 22 and is being delivered through the roll nip at a rate equal to the peripheral speed of the retarding roll 23, the material is compacted or bunched together in the compacting zone 88*a* above the roll nip. The extent to which the material is compacted in the compacting space will, of course, be determined by the relative peripheral speeds of the feeding and retarding rolls 22, 23 and is adjustable within limits by regulation of the P.I.V. drive unit 38. In this respect, compacted material emerging from the zone 88*a* springs out, lengthwise, to a certain extent, as longitudinal compressive forces are released. Thus, fabric on the exit side of the zone 88*a* may be about ⅓ longer than fabric within the zone, and this factor should be taken into consideration when setting the relative speeds of the feeding and retarding rolls.

As indicated in FIG. 6, as the material is compacted or bunched together in the compacting zone 88*a*, the thickness of the fabric is increased. Thus, it will be particularly noted that the fabric is not subjected to localized pressure between the shoe 74 and the surface of the feeding roll 22, but is blocked by the terminating edge 83 of the shoe so that the compacted material cannot propagate past the edge 83 in the direction opposite to the direction of fabric movement. This is an advantageous feature in that it avoids unnecessary wear on the roll 22 and fabric as well as unnecessary friction losses.

While the present invention is not restricted to any particular theory of fabric behavior during the compacting process, it is presently believed that when knitted material is compacted in the zone 88*a* the individual knitted loops slide upon each other, lengthwise of the fabric, to an extent such that some buckling and partial up-ending of the individual loops takes place whence stress relieving in the yarn or thread thereof and in the loops themselves is encouraged. While the fabric is in this condition, it is passed between the nip of the feeding and retarding rolls **22, 23** where the fabric is subjected to localized pressure by the confining surfaces of the rolls and also to the heat of both rolls, which are supplied interiorly with steam. The deformed and stress-relieved threads or yarns are thereby, in effect, ironed in place so that as the material leaves the roll nip the yarns retain a predetermined degree of their deformed or compacted condition.

The temperature at which the rolls **22, 23** are maintained does not appear to be critical, with the qualification that it should be at least high enough to vaporize the moisture in the material and have the so-called "ironing" effect on the deformed yarns of the fabric. Satisfactory results have been obtained by passing steam through the rolls at a temperature as low as 250° F. Advantageously, however, the temperature should probably be in the neighborhood of 300° to 350° F.

Heating of the rolls **22, 23** constitutes an important feature of the invention, since it permits a highly effective mechanical compacting of the fabric while in a "dry" state. Thus, an air-dry fabric generally has an inherent moisture content of 4 to 6 percent, which has been found sufficient to effect the desired "ironing" of the compacted fabric. It also is sufficient to assist in the stress relieving which is believed to take place in the compacting zone. This is highly advantageous in that it is thereby possible to avoid the operations of moistening the fabric prior to compacting and, of greater importance, drying the fabric subsequent to the compacting. In this respect, it will be understood that conventional drying apparatus is relatively bulky and requires substantial factory floor space, and also involves considerable power expense. In addition, and of substantial importance is the fact that in such a drying operation substantial precaution must be taken to avoid negation of the compacting by the additional handling necessitated therein.

It should be understood, however, that the present invention does not exclude moistening of the fabric. Thus, certain aspects of the invention presently to be described contemplate the compacting of materials after first moistening them to a rather substantial extent. In such cases, little if any heating of the rolls **22, 23** may be required.

Referring particularly to FIG. 10, there is represented a highly magnified area of plain knit material. As will be observed, the knit fabric material comprises a plurality of transversely propagated yarns **89, 90** disposed in a sinuous manner to form alternate, oppositely disposed loops, such as **89***a*, **89***b*, and **90***a*, **90***b*, the axes of the loops being aligned longitudinally of the material. In each longitudinal row of loops **89***a*, **90***a*, etc., the head or closed end of one loop is interlocked with the base or open end of a longitudinally adjacent loop. In a plain knit fabric, such as shown in FIG. 10, the heads of all the loops lie at one side of the fabric, and this is known as the "rough" side of the fabric. The arrangement is apparent in FIG. 11, wherein it will be observed that the loop heads form relatively sharp projections at the upper surface of the illustrated fabric section, while the lower surface has relatively smooth contours. It is acknowledged, of course, that there are a wide variety of knit fabrics, all of which do not have the exact configuration and characteristics represented in FIGS. 10 and 11. However, for the purpose of this description, it is believed that the illustrated fabric form is adequately representative of most knit fabrics.

When a knit fabric, such as shown in FIGS. 10 and 11, is passed longitudinally through the new compacting apparatus, certain of the rows of yarn loops are engaged by the retarding roll and are traveling at the peripheral speed thereof, while other rows of loops, spaced rearwardly from the first in the direction of fabric movement, are in contact with the feeding roll **22** and are moving at the higher peripheral speed thereof. Accordingly, intermediate rows of loops, and specifically those in the compacting zone **88***a*, will be bunched together, as by sliding upon each other and buckling in a direction transverse of the plane of the material. Thus, a magnified cross-sectional representation of the compacted fabric might appear substantially as shown in FIG. 12. During this reorientation of the loops, stress relieving therein or in the yarn or thread thereof may take place also.

Diagrammatically, the relative relation between the fabric structures before and after compacting is illustrated in FIGS. 13 and 14. In the latter figures, the individual arcuate sections **91** indicate the disposition of individual yarns between adjacent loop heads, as between loop heads **89***a*, **89***b*, for example. The points or ends of the arcuate sections indicate the loop heads.

It will be observed in FIG. 14 that after the fabric has been subjected to compacting in the zone **88***a*, the distance between the loop ends is somewhat shorter and the individual yarns are disposed in a higher arc between the loop ends. Thus, the individual loops are pushed together in a more compact relation and are buckled transversely of the fabric plane. Accordingly, when the partially heated and stress-relieved fabric passes through the roll nip and is subjected to additional heat and pressure from the two rolls, the individual loops may be permanently deformed so that a permanently compacted fabric emerges from the rolls. In this respect, it will be understood that the compaction is not "permanent" in the sense that it is impossible to stretch the fabric into its initial form. However, the fabric is compacted with sufficient permanence that the compacted condition of the fabric will be retained throughout such further operations as may be performed on the fabric in the ordinary course of garment manufacture.

As one of its important aspects, the present invention contemplates the compacting of tubular knitted material, as distinguished from flat material, it being understood, however, that the invention is not limited to tubular materials. Ordinary tubular knit material is formed on circular knitting machines, and has the form of a tube of indefinite length. In order to process the material in tubular form, it is normally necessary that the tube be folded flat and the material handled as a double layer of material. The handling of the material in tubular form creates considerable problems, as will be understood, since as the material passes through the compacting station one layer of the material is in contact with the feeding roll **22**, while the other layer of the doubled material contacts the slower moving retarding roll **23**. Accordingly, there is a tendency for the material to delaminate; that is, for the separate layers of the doubled material to slide relative to each other. This problem is also faced, but to a considearably lesser degree, as the fabric passes between the feed roll and the confining shoe.

Generally, the tubular material as received, has its "rough" surface inside, so that when the material is flat, opposing "rough" layers are in contact. The arrangement is shown diagrammatically in FIG. 15. Accordingly, the material has certain inherent characteristics tending to resist delamination.

One of the improved features of the invention having the effect of avoiding delamination of the doubled fabric resides in the use of a feeding roll **22** having a generally smooth outer surface but with special surface characteristics providing limited gripping action on the fabric. In order to frictionally grip the fabric to the extent necessary to feed the fabric, the surface **77** of the shoe **74** covers a relatively wide arc and provides a large gripping area between the shoe and the feeding roll. However, as the fabric emerges from the lower edge **83** of the shoe, it is unconfined laterally for a short distance through the compacting zone whereby the fabric looses its frictional grip with the roll, and in the localized area of pressure contact at the roll nip the frictional grip formed between the fabric and the feeding roll is considerably less than that formed between the fabric and the relatively rough retarding roll. Accordingly, the fabric has little tendency to move along with the feeding roll after emergence of the fabric into the compacting zone 88*a*.

In order to provide the surface of the feeding roll 22 with the desired frictional gripping characteristics, the roll surface is advantageously provided with a mild, shallow knurl and subjected to a so-called light etch. The etching imparts to the surface of the shallow knurled feeding roll a satin-like finish which, although it may not be particularly perceptible to the feel, increases the co-efficient of friction between the roll surface and the fabric. This treatment of the surface of the feeding roll is advantageous in that it increases the co-efficient of friction between the roll surface and the material without materially increasing the tendency for the contacting layer of material to stick to the roll as it passes through the roll nip. In accordance with the invention, the contacting layer of material is gripped by the feeding roll 22 at the roll nip with less force than the internal surfaces of the doubled material grip each other at this point so that delamination does not result when one layer of the doubled material assumes the speed of the retarding roll.

Acceptable alternate forms of feeding rolls are shown in FIGS. 7 and 8. The roll 92 in FIG. 7 has shallow circumferentially spaced longitudinal grooves formed in the surface thereof, while the roll 93 in FIG. 8 has oppositely disposed helical grooves formed therein. The alternate roll forms are useful in avoiding delamination of the material since, it is believed, the irregularities in the roll surfaces are impressed into both layers of the tubular fabric, as the fabric passes through the roll nip, so that the fabric layers are locked to some extent against longitudinal relative movement. The grooves of the rolls 92, 93 should not, however, be sufficiently wide or deep as to tend to cause the material to adhere to the feeding roll in passing through the nip.

Another improved feature which aids greatly in avoiding any tendency of the fabric to delaminate is the arrangement of the shoe 74 with respect to the feeding roll 22 in a manner such that the fabric is not pinched against the feeding roll or otherwise subjected to substantial localized pressure even at the terminating edge 83 of the shoe. To this end, the shoe 74 may be accurately adjusted by means of screws 81, 82 and 67, so that the fabric is pressed against the roll 22 over a large area and with sufficient firmness to obtain driving friction while avoiding such localized pressure as may be classified as "pinching" of the fabric.

In FIG. 9 there is shown a novel form of retarding roll for use when the material is to be moistened prior to compacting and may be passed through the compacting station in the absence of substantial heat. Experiments have shown that if the fabric is moistened to the extent necessary for compacting without heat (60–80 percent moisture), there is a tendency for the doubled layers of material to delaminate, rendering it practically impossible to compact the material satisfactorily in the absence of special means to avoid delamination. Accordingly, for wet compacting we may advantageously employ a retarding roll 94 having an outer surface covering 95 which is adapted to positively grip the both layers of the doubled material as it passes through the roll nip, while positively releasing the fabric as soon as it emerges from the nip. The improved surface covering is in the form of generally conventional card clothing having a base layer 96 from which project a multitude of fine wires 97. In accordance with the invention, the projecting portions of the wires 97 are embedded in a continuous layer 98 of resilient material, such as rubber, in such a manner that the top surface of the rubber layer or filler lies at the same level as the tops of the wires 97. As will be observed in FIG. 9, as the fabric 11 passes through the nip between rolls 22 and 94 the fabric is compressed between the hard surface of the substantially non-resilient steel feeding roll 22 and the surface of the resilient rubber filler 98. Accordingly, the rubber filler is deflected inwardly and the ends of the wires 97 are projected into the fabric, advantageously into both layers thereof. It will be understood in this respect, that the spacing between rolls 22 and 94 should be such that the ends of the wires 97 pass very close to the surface of the feeding roll 22, at the roll nip.

As the fabric 11 emerges from the roll nip, the confining pressure exerted on the fabric by the steel feeding roll 22 is released and the rubber filler material 98 springs outwardly, automatically stripping the fabric 11 from the projecting ends of the wires 97 and freeing the fabric entirely from the retarding roll 94.

It is generally contemplated that a retarding roll of the type shown in FIG. 9 will be used where the process is to be carried out in the absence of substantial heat. However, it will be understood that, in proper cases, at least the feeding roll 22 may be heated. It is also possible that the retarding roll 94 may be heated in some cases, although it will be understood that the surface covering 95 will tend to impede the flow of heat into the fabric from the roll 94.

One of the outstanding advantages of the invention resides in the fact that materials may be effectively compacted in a continuous economical process to a point where the compacted length of the fabric is substantially less than its original length. As a general rule, compacting or mechanically pre-shrinking is intended to stabilize the fabric so that during subsequent laundering the fabric does not shrink. However, wherever necessary or desirable, the method and apparatus of the present invention may be employed to "overcompact" the knitted fabric to less than 50 percent of its original length; and, in this respect, it is contemplated that a fabric overcompacted to this extent may be provided with a suitable resin binder, imparting characteristics of longitudinal resilience to knitted fabrics, which are normally substantially resilient in transverse direction only.

The compacting of fabric in accordance with the invention involves substantial improvements over prior compacting methods in that greater control is afforded over the extent of compacting effected, and the material is acted upon in such a way as to avoid unnecessarily abrading the fabric and/or components of the compacting apparatus.

In accordance with the invention, compacting forces are applied continuously to successive short increments of the fabric, whereby to deform the fabric elements transversely of the plane of the fabric and/or to slide the fabric elements with respect to each other during which reorientation stress relieving may take place. The deformed and stress-relieved elements are then pressed in place with substantial permanence, either by simultaneous application of heat and pressure to the confined elements in the absence of substantial or excess moisture, or by the application of pressure alone, in the absence of substantial heat, when the fabric has been artificially moistened.

The new apparatus requires substantially less power and factory floor space than has been necessary heretofore. Perhaps most important, in this regard, is the fact that the new compacting method may be carried out upon air-dry fabric, without the addition thereto of any moisture. This eliminates the apparatus for and the expense of moistening as well as the much greater expense of capital and floor space as heretofore required in drying the fabric after moistening. It furthermore eliminates the difficult problem of handling compacted fabric during a drying operation without harmful effect on the "compacted" characteristic thereof. Moreover, with the new apparatus and method, compacting forces are applied to the fabric in such a way as to be efficiently productive of compacting action and without the inefficiencies heretofore created in the use of power to pinch the fabric and/or to deform one or more resilient components of the compacting apparatus.

It should be understood that many of the theories advanced herein are not intended to constitute limitations on the invention and are not known to be accurate. Rather, such theories merely represent an attempt to explain the behavior of fabrics treated in accordance with the new method, in a manner which is consistent with the results obtained. Likewise, although the invention has been explained largely with reference to the compacting of tubular knit fabrics, it is contemplated that many, if not all, types of frabric may effectively be compacted by the techniques and by the apparatus before described. Accordingly, reference should be made to the following appended claims in determining the full scope of the invention.

The term "fabric," as used in the appended claims and in the foregoing specification, should be construed to include various flat, web materials, whether fibrous or not, which are capable of being subjected usefully to the treating methods disclosed.

We claim:

1. The method of compressively treating fibrous web material which comprises feeding said material in a positive manner and at a first predetermined uniform speed substantially to the entry line of a treating zone by closely confining both principal surfaces of said material to a predetermined path during said feeding, discontinuing said positive feeding and said close confining substantially at said entry line, retarding said material to a second predetermined uniform speed at an exit line of said treating zone, whereby said material is caused to decelerate and decrease in length and thereby to increase in thickness in passage through said zone, the increased thickness of said material being substantially greater than that of said predetermined path whereby decelerating portions of said fabric are confined substantially to said treating zone, said predetermined path being of a length several times larger than the length of said treating zone, and subjecting said material to heat and substantial localized pressure at the exit line of said treating zone.

2. The method of compressively treating fibrous web material which comprises feeding said material in a positive manner and at a first predetermined uniform speed substantially to the entry line of a treating zone to closely confining both principal surfaces of the material to a predetermined path during said feeding, discontinuing said positive feeding and said close confining substantially at said entry line, causing said material to increase considerably in thickness substantially at said entry line and to decrease in length by decelerating the material to a second predetermined uniform speed in a treating zone of predetermined length considerably less than the length of said path, the increased thickness of said material being substantially greater than that of said predetermined path whereby the decelerating portions of said fabric are confined substantially to said treating zone, and subjecting said material to heat and localized pressure as the material leaves said treating zone.

3. The method of claim 2, in which the web material is tubular knitted fabric in flat form, said fabric being fed by applying feeding force to one outside principal surface thereof, and said fabric being decelerated by applying retarding force to the other outside principal surface thereof.

4. Apparatus of the character described, which comprises a feeding roller, means to drive said feeding roller at a first predetermined uniform peripheral speed, a retarding roller, means to drive said retarding roller at a second predetermined uniform peripheral speed, said second peripheral speed being related to and slower than said first peripheral speed, said feeding and retarding rollers being mounted to form a nip and having surface characteristics such that said retarding roller has a more positive grip than said feeding roller on material passing through said nip, a confining shoe positioned adjacent said feeding roller and having an arcuate confining surface extending over a substantial arcuate surface portion of said feeding roller, said feeding roller and said confining surface forming a confined path for the passage of material in positive frictional feeding engagement with said feeding roller, said confining shoe having a terminating edge positioned a predetermined distance from said nip, said predetermined distance being substantially less than the length of said confined path, said feeding roller and the portion of said shoe in the immediate region of said terminating edge forming an entry of a treating zone, said nip forming an exit of said treating zone, said treating zone accommodating substantial increase in the thickness of material emerging from said confined path whereby lengthwise compression of the material is limited to said treating zone, and means to heat said rollers.

5. Apparatus of the character described, which comprises a feeding roller formed of non-resilient material, a retarding roller formed of non-resilient material, means to drive said rollers at predetermined, uniform and related speeds such that the peripheral speed of the feeding roller is greater than that of the retarding roller, said rollers forming a nip, a confining shoe mounted adjacent said feeding roller and having a confining surface disposed adjacent a substantial surface portion of said feeding roller and forming therewith an elongated, confined path for the passage of material in positive frictional feeding engagement with said feeding roller, said confining shoe having a terminating edge and, together with said feeding and retarding rollers, forming a zone of increased thickness in the immediate region of said terminating edge, said zone of increased thickness and said nip defining the entry and exit ends, respectively, of a compressive treating zone, the length of said treating zone being substantially less than the length of said confined path, means for heating said rollers, and means acting upon said rollers for applying substantial localized pressure to material passing through said nip.

6. The apparatus of claim 5 in which said feeding and retarding rollers are formed of steel, the feeding roller having a mildy etched outer surface and said retarding roller having a roughened outer surface.

7. The apparatus of claim 5, in which said retarding roll has a surface layer comprising a multitude of generally radially projecting wires and a resilient filler material surrounding projecting tip portions of said wires, said wires and filler normally forming a relatively smooth outer surface, said feeding and retarding rolls being so spaced that the respective outer surfaces thereof are spaced apart at the roll nip a distance substantially less than the thickness of material compacted in said zone.

8. The apparatus of claim 7, in which said surface layer is card clothing provided with a rubber outer surface layer surrounding the projecting tips of said wires.

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