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APPARATUS AND PROCESS FOR CONTINUOUSLY STEAMING TEXTILE FIBER MATERIALS

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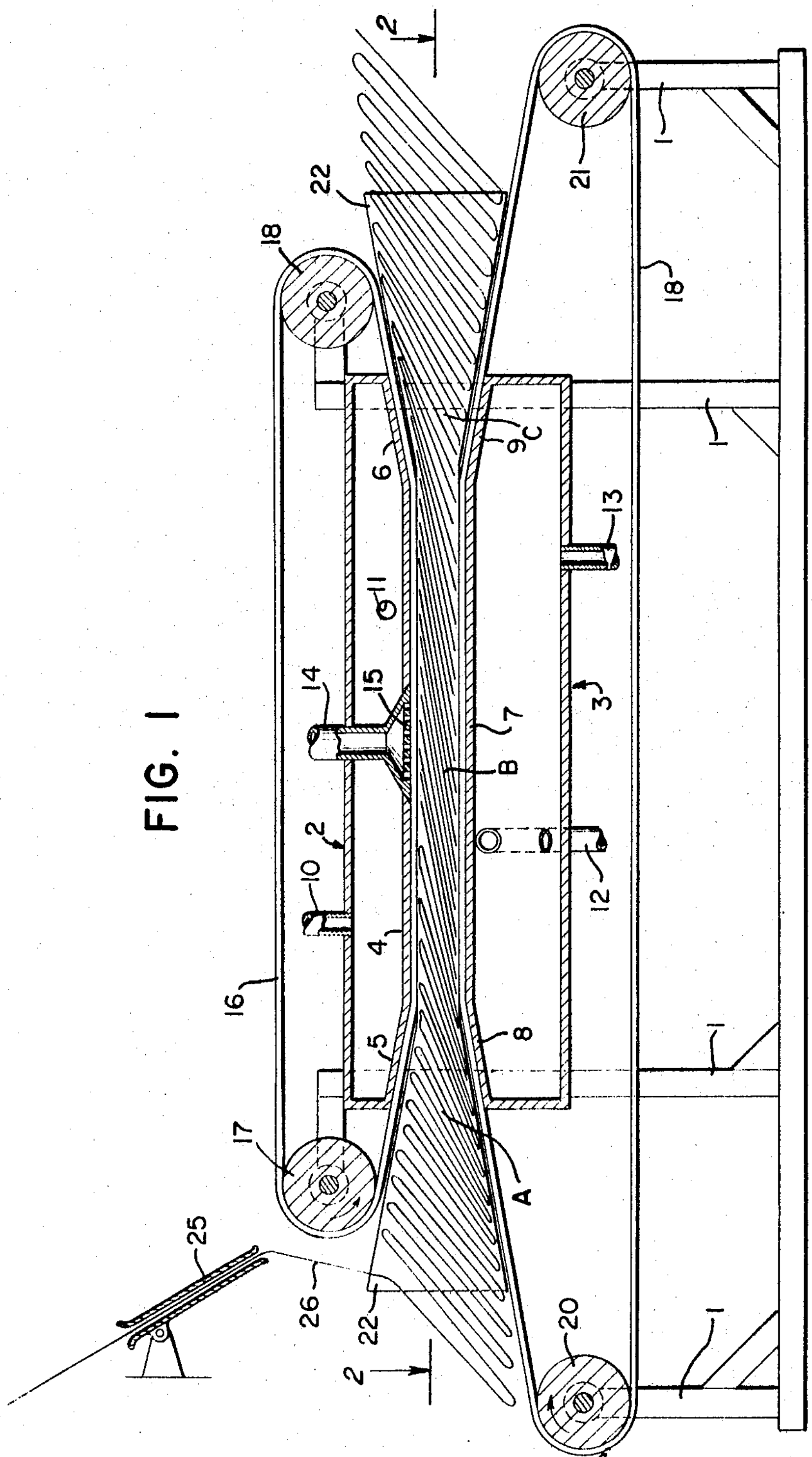


INVENTOR,
LEO DRAGO

BY Stowell & Stowell

ATTORNEYS

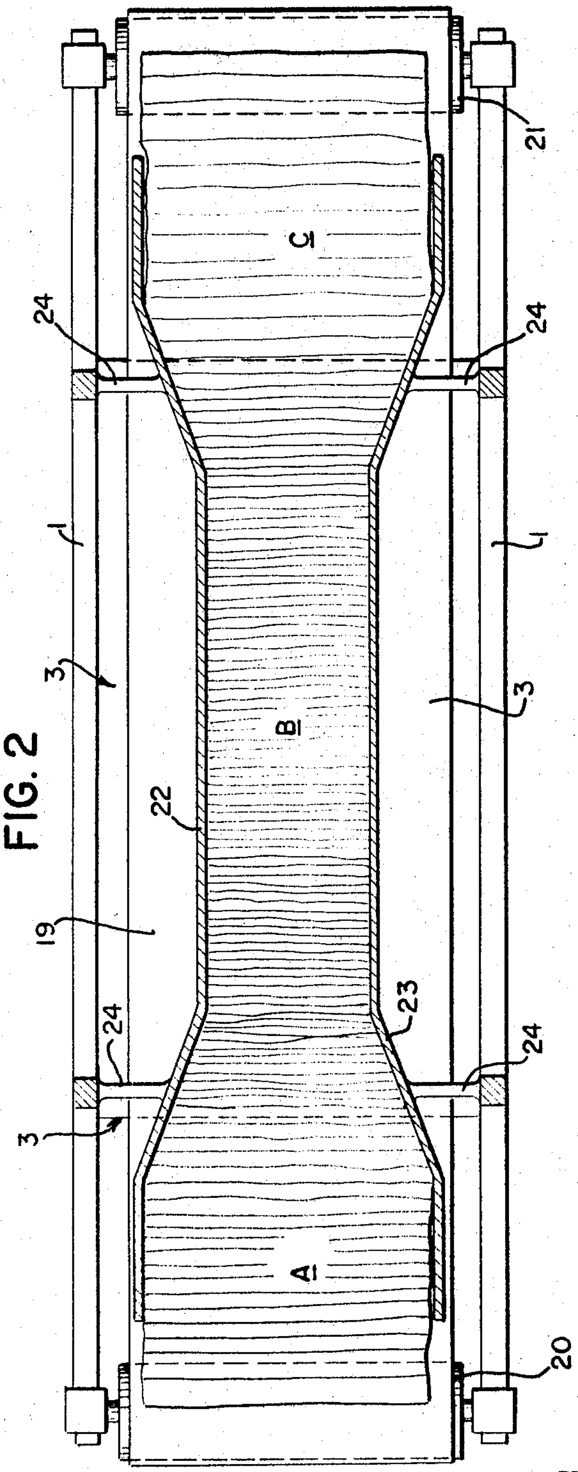


FIG. 2

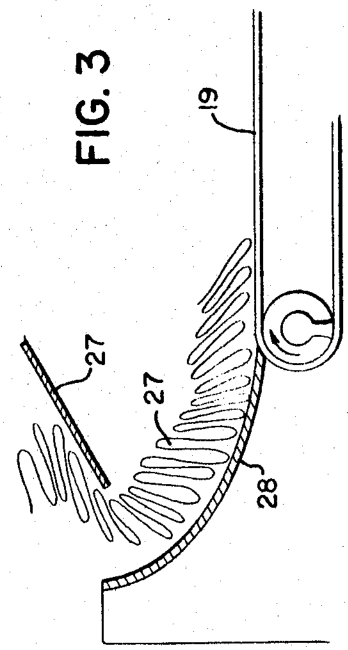


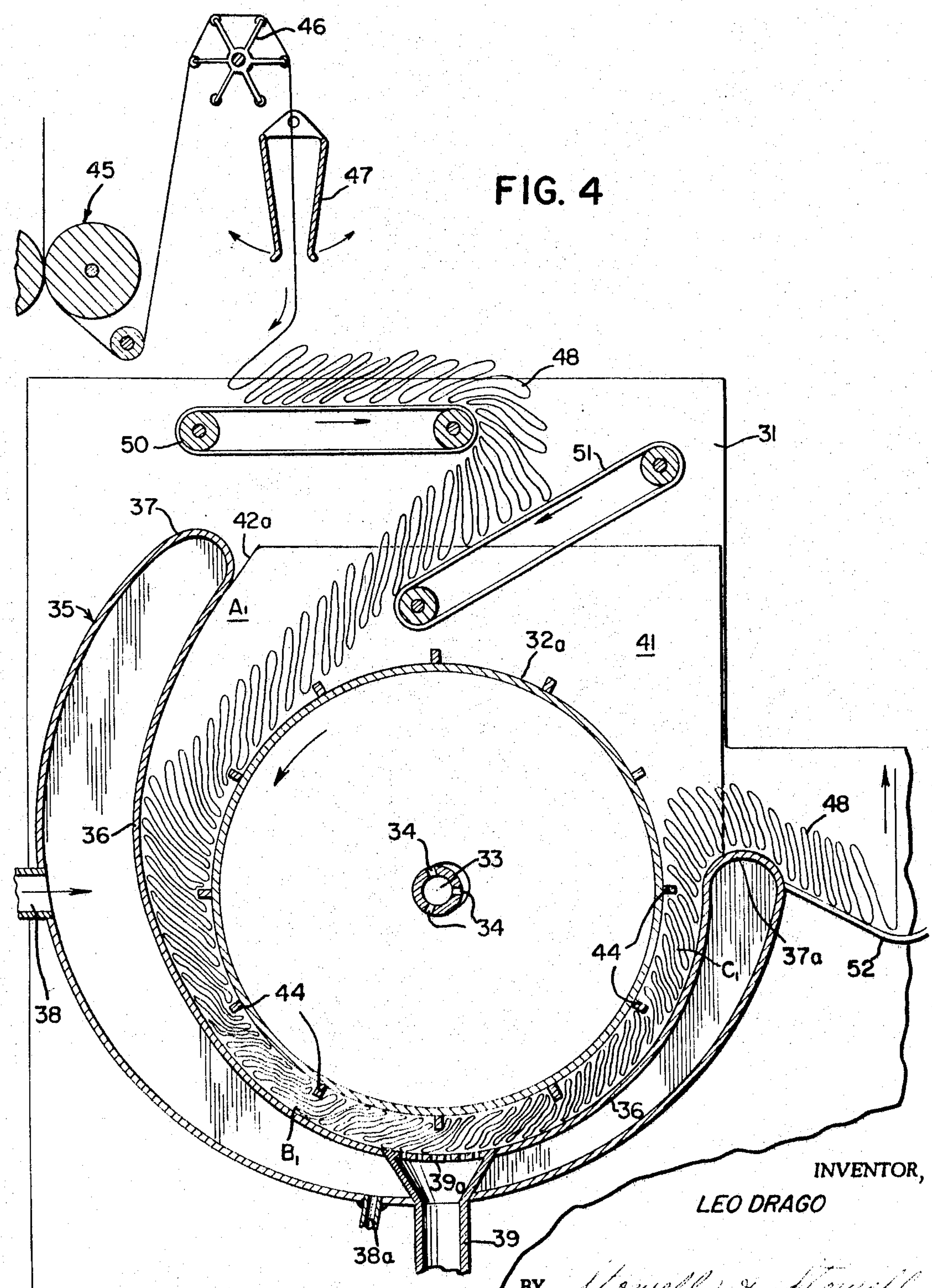
FIG. 3

INVENTOR,
LEO DRAGO

BY Stowell & Stowell

ATTORNEYS

FIG. 4



INVENTOR,
LEO DRAGO

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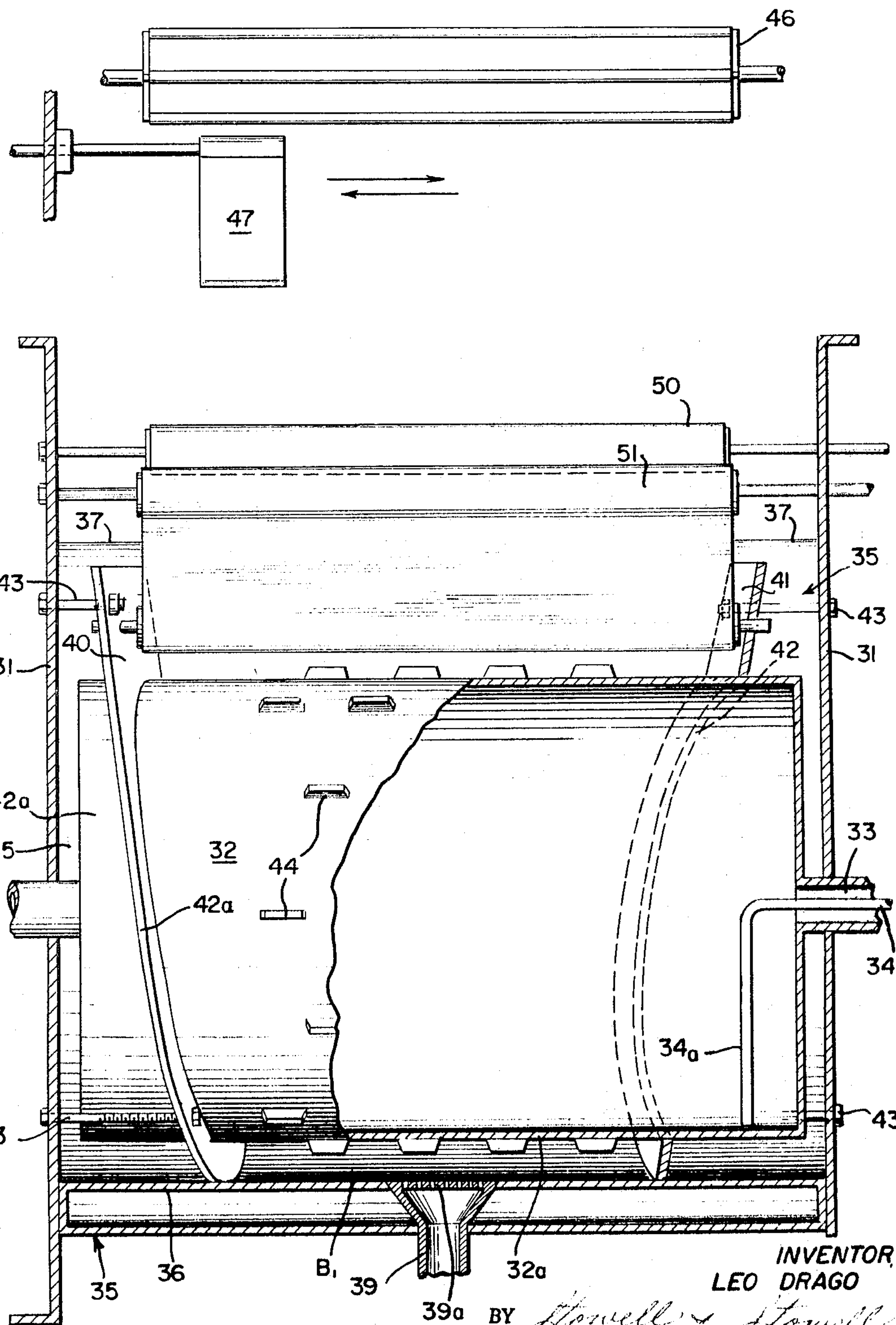

FIG. 5

INVENTOR
LEO DRAGO
BY Stowell & Stowell
ATTORNEYS

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APPARATUS AND PROCESS FOR CONTINUOUSLY STEAMING TEXTILE FIBER MATERIALS

Leo Drago, Schio, Italy, assignor to Ilma Industria Lavorazioni Metalli Antiacidi S.A.S., Schio, Italy, and J. R. Geigy A.G., Basel, Switzerland

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U.S. Cl. 8—149.3 27 Claims

ABSTRACT OF THE DISCLOSURE

Apparatus for the continuous dyeing of textile fiber materials which, in contrast to known apparatus, comprises an elongated passage consisting of a first zone adjacent to the entry of the passage in which zone the cross sectional area of the passage gradually decreases to a minimum area which is then held constant throughout a central zone, whereupon the cross sectional area of the passage again increases.

Means are provided for introducing textile fiber material, preferably in the form of folds several of which are partially superimposed upon each other, for conveying a sequence of such folds continuously through the passage, for withdrawing the material from the exit of the passage, and for introducing steam under pressure into the central zone of the passage directly into contact with the material passing therethrough.

In a preferred embodiment, the passage formed between a rotatable drum and a tub-shaped container in which the drum is mounted.

A process for continuously treating textile fiber material with steam under pressure wherein the textile fiber material is introduced into a first zone wherein the material is gradually increasingly compressed to a maximum compression, whereupon the compressed material is passed through a second zone in which its compression is substantially maintained while steam is introduced into the zone, directly into the material, under a pressure above ambient pressure, and finally the steamed material is gradually decompressed in a third zone. Textile materials are for instance polyester fibers, natural and synthetic polyamide fibers, polyolefin fibers, polyurethane fibers, and polyacrylonitrile fibers, polyester fibers being preferred, especially polyester tow laid in folds.

Description of the invention

This invention relates to apparatus for the continuous steaming of textile fiber material, and to a process for the continuous steaming of such material, especially in the form of tops and tow.

It is well known to treat textile fiber material with steam by introducing such material into a chamber, injecting steam into the latter, for instance under pressure, and then, after the fiber material has been steam-treated for the desired period, withdrawing the same from the chamber. This method of steam-treatment always involves a serious problem of how to achieve the necessary tight sealing of the chamber during the injection of steam thereinto, especially when operating with steam at superatmospheric pressures. This operation is carried out economically if the major portion or all of the steam is absorbed by the material, with negligible or no losses at all of steam through leakage of steam from the apparatus to the outside.

It is possible to obtain satisfactory sealing through the use of tight sealing doors, when carrying out the treatment in intermittent runs; however, in a continuous treatment, such doors must be replaced by pairs of rollers, for example by introducing the textile material between the rollers of one pair into the steaming chamber, and by withdrawing the material between another pair of rollers. In either case, satisfactory sealing requires special equipment and represents a serious problem.

It has also been suggested, for example in German Patent 933,922 published on Nov. 11, 1954, to Emil Mende, and in British Patent 1,022,086 to Hans Fleissner et al., published on Mar. 9, 1966, to store the textile material in folds placed in sequentially arranged movable chambers constituted by the sectors of a rotary drum and separated from one another by partition walls extending radially from the drum axis, the outer rims of the partition walls coacting with a conveyor belt or stationary wall to effect a tight sealing by compressing a single layer of material therebetween. In order to achieve satisfactory sealing, considerable pressure had to be exerted on the single layer of textile material so that penetration of steam into such zones of the layer in contact with the outer rim of the aforesaid partition walls was insufficient and, for instance, when continuous steaming was to serve for fixing dyestuff applied by padding on the textile fibers, stripes of insufficiently fixed dye became visible on the steamed material. Moreover, the high mechanical stress applied to these sealing zones of the material is in itself undesirable. As another drawback of these known apparatus, withdrawal of the steamed material from under a stack of folds in a compartment to be emptied would easily lead to entanglement of the material being withdrawn.

It is also known to steam pad-dyed textile fibers, especially acrylic or polyester fibers in the form of tow or tops in a long tunnel through which the fiber material is drawn with the aid of a chain. The material is strongly compressed in the entry and the exit zone of the tunnel while being intermediarily decompressed in the central tunnel zone in which steam is introduced into the material under considerable pressure. In order to obtain the necessary very tight sealing at the tunnel entry and exit and avoid steam losses therethrough, it is necessary to compress the textile material very strongly; moreover the mode of conveyance and compression in this known apparatus impart to the material a very pronounced crimp. This is undesirable for many types of further processing of the steamed material, especially in the case of tops, leading for instance to difficulties in subsequent spinning.

It is therefore an object of the present invention to provide apparatus free from the aforesaid drawbacks, and to provide a process for the continuous steaming of textile fibers, especially in order to fix dyestuff previously applied by padding or printing to the fibers, on the latter in an even manner by steaming under pressure above ambient pressure, without any undue loss of steam.

This object and others which will become apparent as the description of the invention proceeds, are attained by the apparatus and process of the present invention, which comprises, as an important feature, continuously advancing a mass of textile material, preferably in the form of a sequence of folds several of which are always partially superimposed upon one another, through an elongated passage, the cross sectional area of which decreases gradually to a minimum in the first region extending from an entry opening of the passage in the direction toward the central region of the passage.

Due to the fact that the mass of material being conveyed through the passage is being gradually increasingly compressed in the said first region, and is maintained at maximal compression throughout the central region, while only being gradually decompressed in the said third region, a satisfactorily tight sealing of the mass of textile fibers against the top, bottom and side walls of the passage is achieved, whereby losses of steam from the central region are essentially avoided, the bulk of the steam being absorbed by the fiber material, and a substantial excess pressure above ambient pressure can be maintained in the central region.

The compressed textile material maintains a tight seal to prevent steam leakage not only from the central region of the passage but also some length ahead and for some length behind that central region, i.e. in the preceding first region into which the textile material is being fed, and in the subsequent third region at the exit end of which the completely decompressed, steamed material is being withdrawn. Because of this good sealing effect by the textile material itself, it is not necessary to weld the top, bottom and side walls of the aforesaid passage tightly together; it is possible to mount them in head-to-tail assembly without use of special sealing members, and it is even possible to leave a certain amount of play, for instance between the side-walls on the one hand, and the top and bottom walls of the passage, on the other hand.

More particularly an apparatus according to the invention comprises an upper container part the surface of which constitutes an elongated bottom wall, a lower container part the surface of which constitutes an elongated top wall, said upper and lower containers being so arranged relative to each other that the central longitudinal axes of said bottom wall and said top wall are in the same plane, and that a free passage is left between said bottom wall of said upper container and said top wall of said lower container, elongated plates extending along both sides of said passage to form side walls thereof limiting the lateral extension of said passage to within the transverse widths of said bottom and top walls, and leaving an open entry and an open exit of said passage, conveying means adapted for conveying a mass of textile fiber material through said passage from the entry to the exit opening of the latter, feeding means adapted for feeding textile fiber material to the entry of said passage, discharge means adapted for withdrawing said mass of fiber material from the exit of said passage, means for heating said bottom wall of said upper container or said top wall of said lower container or both said walls, steam introducing means adapted for introducing live steam under pressure directly into the central region of said passage, at least one of said bottom wall, top wall and two side walls being so shaped that the cross sectional area of said passage decreases gradually to a minimum in a first region extending from said passage entry in the direction toward the central region of said passage, remains substantially constant throughout the central region of said passage and increases in a third region extending from the end of said central region to the exit of said passage.

Preferably, the width of the elongated top wall of the lower container is about equal to or slightly larger than the width of the elongated bottom wall of the upper container, and the length of the top wall of the lower container is preferably longer than and extends at both ends beyond the ends of said bottom wall of the upper container.

In a first embodiment of the apparatus according to the invention the said upper and lower walls are substantially planar and are converging from the ends of the upper and lower containers at the entry side of the passage, while remaining substantially parallel to each other throughout the central passage region, and diverging from each other from the end of the central region toward the ends of the upper and lower containers at the exit side of the passage.

It is also generally preferred that the side walls of the passage are substantially planar and converge toward each other from the entry of the passage toward the central passage region, while remaining substantially parallel with each other throughout the central region and diverging from each other from the end of the central region toward the exit of the passage.

In the aforesaid first embodiment of the apparatus according to the invention, the conveying means comprises a first conveyor belt associated with said lower container and mounted on the latter for movement along the top wall of the lower container from the entry to the exit of the passage, and means for driving said first conveyor belt in the direction from the entry to the exit of the passage through the latter.

Preferably, the conveying means in this embodiment further comprises a second conveyor belt associated with said upper container and mounted on the latter for movement along the bottom wall thereof from the entry to the exit of said passage, and means for driving the second conveyor belt in the direction from the entry to the exit of the passage through the latter in unison with the first conveyor belt.

In this embodiment the side walls of the passage are mounted on the lower container in such a manner as to extend with their lower rims above said first conveyor belt with sufficient play to permit unimpeded operation of the latter. In the case of a second conveyor belt being provided, the top rims of the side walls must leave sufficient play for unimpeded operation of the second belt. The gaps between the lower said wall rims and the upper surface of the first conveyor belt, and, if a second belt is present, between the lower surface of the latter and the upper side wall rims, must be narrow enough to permit tight sealing of the gaps by the textile material conveyed on the first belt or between the first and second belts, when the material is compressed in the central region of the passage, thereby preventing substantial loss of steam from that region.

The feeding means are preferably adapted for laying the fiber material in a sequence of folds on the first conveyor belt, in such a manner that several, preferably three or more of the folds are always partially super-imposed upon each other. The feeding means further preferably comprises means for placing the folds on the said conveyor belt in such a manner that the top end of each fold is tipped rearward relative to its foot end whereby the conveyor belt pulls each fold by its foot end through the passage, rather than pushing the fold through the passage as would be the case if the folds were tipped forward instead of rearward. The latter arrangement offers less friction than the former.

In a preferred embodiment of the apparatus according to the invention, the upper container is a rotatable cylindrical drum and the lower container is tub-shaped and surrounds the drum at the bottom and on both sides of the cylindrical drum surface, the central longitudinal axis of the top wall of the tub-shaped lower container extending in the central plane perpendicular to the drum axis, and having a curvature such that the central passage region of constant minimum cross-sectional area extends about the lowermost zone between the said drum and the top wall of the said tub-shaped lower container.

In this preferred embodiment, the drum surface is provided with projections which must be sufficiently short to leave adequate space between the rim of these projections and the opposite top wall of the tub-shaped container for several layers of folded material, in compressed state, even when passing through the lowermost zone between the drum surface and the said top container surface. Furthermore, the conveying means in this embodiment comprises means for rotating the drum at an adequate speed permitting sufficient staying time for the textile material in the central region in which steaming under pressure takes place.

In this preferred embodiment, the feeding means comprises means for introducing the textile fiber material in the form of a sequence of folds, several of which are always partly superimposed upon each other, into the passage between the drum and the top wall of the tub-shaped container at the entry opening of the passage, from which opening the projections on the drum are moved during rotation of the latter toward the said lowermost zone and further from there toward the exit of the passage on the opposite side of the cylindrical drum surface. Preferably the said feeding means further comprises means for tilting the folds of the said material in such a manner that each fold end coming into contact with the top wall of the said tub-shaped container is tipped rearward relative to the opposite end of the same fold which comes into contact with the cylindrical surface of the drum, whereby the latter surface in cooperation with the said projections thereon pulls the folds through said passage, rather than pushing them therethrough.

The discharge means in this embodiment preferably comprises means for tilting the folds emerging from the passage exit in such a manner that the end of each fold which was in contact with the drum surface is tipped rearward of the opposite end of the same fold, which was in contact with the top surface of the tub-shaped container, whereby removal of the folds from the apparatus is greatly facilitated.

In this preferred embodiment, the steam introducing means are best mounted in the tub-shaped container so as to open, for instance in a plurality of perforations, through the top wall of the latter into the central region of the passage between the cylindrical drum surface and the tub-shaped container, i.e. in the lowermost zone therebetween.

The process for continuously treating textile fiber material with steam under pressure, according to the invention comprises introducing a mass of textile fiber material into a first zone wherein said mass is gradually increasingly compressed to a maximum compression, passing the compressed material through a second zone in which its compression is maintained substantially constant and wherein saturated steam is introduced under a pressure above ambient pressure, and then gradually decompressing the steamed material in a third zone.

Among the textile fiber material which can be steamed by the process according to the invention there are suitable such organic textile fibers as, for instance natural or synthetic polyamide fibers, e.g. wool, silk, nylon 6, nylon 66, nylon 11 and also acid-modified synthetic polyamide fibers such as Perlon N, furthermore, polyolefin fibers such as Polycrest, polyurethane fibers and homopolymer or copolymer acrylic fibers such as Orlon, Acrilan and Dralon.

Best suited for use in the process according to the invention are, however, polyester fibers such as cellulose di-, 2½- and tri-acetate and particularly high molecular weight esters of aromatic dicarboxylic acids with polyols, e.g. polyethylene glycol esters of terephthalic acid, such as Dacron. Most suitable are such polyester fibers in the form of tow or tops, which are preferably folded in the manner described hereinbefore.

The staying time of the material in the central steaming zone and the temperature applied thereto, which is of course a well-known function of the pressure under which the steam is applied, depend always on the nature of the fibers being treated.

Thus, polyester fibers are passed through the central zone at a rate to have a staying time therein of about 20 to 60 minutes. The temperature applied to this kind of material ranges from about 120 to 140° C., which corresponds to a steam pressure of about 2 to 3.6 atm. above ambient pressure.

In the case of synthetic polyamide fibers, such as nylon, a staying time of 10 to 20 minutes and a temperature of 120° C. are adequate.

In the case of polyacrylonitrile fibers, a staying time of about 10 to 40 minutes and a temperature of 105° C. are recommended.

The apparatus and process according to the invention are particularly useful in the continuous dyeing and printing of textile fibers in which they are used to develop (fix) the dyestuff which has been applied to the fibers contained in a pad liquor on a padding machine. The padded material is directly introduced from the pad mangle into the apparatus according to the invention in which the fixation (development) of the fibers is carried out with the aid of saturated steam the introduction of which has been described hereinbefore.

The invention will be explained in more detail in connection with the accompanying drawings which represent a number of embodiments of the apparatus according to the invention suitable for carrying out the above described process in practice.

In these drawings:

FIGURE 1 is a longitudinal sectional, somewhat schematical view of a first embodiment of the apparatus according to the invention;

FIGURE 2 is a cross sectional view taken along the line II—II of FIGURE 1;

FIGURE 3 shows a preferred modified detail of the embodiment shown in FIGURES 1 and 2;

FIGURE 4 is a longitudinal sectional view of a preferred embodiment of the apparatus according to the invention; and

FIGURE 5 is an elevational view, somewhat schematically and partly in section, of the embodiment shown in FIGURE 4.

In the embodiment shown in FIGURES 1 and 2, reference numeral **1** designates a frame on which there are mounted an elongated upper box **2** and, below the latter so as to leave a space therebetween an elongated lower box **3**. The bottom of upper box **2** has a central planar portion and, toward the opposite ends of the box, outwardly and upwardly inclined end portions **5** and **6**, whereas the top wall of the lower box **3** has a central planar portion **7** extending in a horizontal plane parallel to the central bottom portion **4** of upper box **2**, and furthermore two flat downwardly and outwardly inclined end portions **8** and **9**.

Upper box **2** can be heated by introducing steam thereto via a pipe **10** and water condensation can be drained from this box through an outlet pipe **11**. Likewise, lower box **3** can be heated by introducing steam through a pipe **12** and drained through a pipe **13**.

A pipe **14** serving for the introducion of steam into the interspace between upper box **2** and lower box **3** is mounted in a tightly sealed manner in the upper box and opens in the said central portion **4** of the bottom wall thereof, its opening being covered by a grid **15**. Steam fed through pipe **14** can for instance be under a pressure ranging from 1 to 4 atmospheres absolute. By way of example, saturated steam of 6 atmospheres can be reduced in a reducing valve (not shown) to about 3.6 atmospheres absolute and the resulting superheated steam having a temperature of up to 140° C., can be introduced via pipe **14** directly into the interspace between boxes **2** and **3**.

At the opposite ends of box **2** there are mounted a drive roller **17** and a return roller **18**, respectively, about which there is mounted a conveyor belt **16**, the lower reach of which passes from roller **17**, as indicated by an arrow at that roller, through the interspace in contact with the bottom wall of box **2** over the entire length of the latter, to roller **18**. In an analogous manner, a drive roller **20** and return roller **21** are mounted on frame **1** spacedly from the end walls of elongated box **3** and a conveyor belt **19** is mounted about these two rollers **20** and **21** so as to pass with its upper reach from roller **20** to roller **21** through the interspace between boxes **2** and **3** in contact with the top wall of box **3** over the entire length of the latter. Drive means such as in an electric motor (not shown) are provided to operate drive rollers **17** and **20** at the same speed.

Conveyor belt **16** is provided with perforations or mesh that will permit the passage of steam therethrough.

The interspace between the bottom wall of box **2** and the top wall of box **3** is closed on its opposite long sides by walls **22** and **23** which need not form tightly sealed joints with the said top and bottom walls. On the contrary, the edges of walls **22** and **23** can be mounted so as to leave a slight gap between these side walls and the aforesaid top and bottom walls, which gap is large enough to allow for the passage of conveyor belts **16** and **19** therethrough. Side walls **22** and **23** are held at the necessary distance from the said top and bottom by being mounted on brackets **24** in frame **1**. In the embodiment of FIGURES 1 and 2 side walls **22** and **23** have central portions at a distance from each other which is shorter than the width of the bottom and top walls of the lower and upper boxes **2** and **3**, respectively, thereby confining the interspace between these two side walls, the central bottom wall portion **4** of upper box **2** and the central top wall portion **7** of lower box **3** in a central channel zone B, to a constant minimum cross sectional area.

From the ends of zone B, side walls **22** and **23** diverge from each other in the direction towards rollers **17** and **20** on the one hand and **18** and **21** on the other hand, thereby forming together with inclined wall portions **5** and **8** an entry zone A of the interspace between boxes **2** and **3**, the cross sectional area of which gradually decreases to the minimum area, maintained in zone B, and together with inclined wall portions **6** and **9** an exit zone C of the same interspace, the cross sectional area of which gradually increases from the minimum area of zone B toward the ends of boxes **2** and **3** on the side of rollers **18** and **21**.

Rollers **20** and **21** of conveyor belt **19** are positioned at a greater distance from the respective end walls of box **3** than are rollers **17** and **18** relative to the end faces of box **2**. A conventional folding device schematically indicated at **25** is mounted above the upwardly moving portion of the upper reach of conveyor belt **19** which extends beyond conveyor belt **16** on the side of roller **17**. This folding device **25** is thus adapted for laying folds of textile material **26** onto the upper reach of belt **19** in such a manner that always several successive folds are partially overlapping each other. This can be achieved easily by controlling the speed at which the folds are being formed, and the angle and speed at which the pendular motion of device **25** is set.

As belt **19** moves upwardly into zone A of the interspace betwen boxes **2** and **3**, the folded material **26** becomes enclosed between conveyor belts **19** and **16** below and above and by the inclined portions of the side walls **22** and **23** and gradually more and more compressed as the cross sectional area between these parts decreases until maximum compression is reached in the beginning of zone B. Simultaneously, the folded material is being heated indirectly through the bottom and top walls of boxes **2** and **3**, respectively, by the steam introduced into these boxes. As the folded material passes under maximum compression through zone B, it is penetrated by steam issuing from pipe **14** through grid **15** and through conveyor belt **16**.

Due to the tight sealing effected by the textile material pressing against the conveyor belts above and below and against the side walls in minimum cross sectional zone B, steam under pressure will escape from the material only in insignificant amounts or not at all, while the major portion of the steam is adsorbed in the material. Due to the high compression of the material in zone B steam from pipe **14** can only penetrate the material slowly and with a significant drop in pressure. For example, if the cross sectional area of zone B is 4 x 70 cm. and the length of zone B is 150 cm., and the folded material is compressed therein, for example, to an apparent density of 700 g./dm.^{3}, the flow rate of steam escaping from the interspace between boxes **2** and **3** can be held as low as about 1 to 5 kg. per hour, even if the folded material is impregnated in the central zone B with steam

issuing from pipe **14** as saturation pressure, e.g. 3.6 atmospheres absolute. As the folded and steamed material emerges form zone B, it is gradually reexpanded in zone C and decompressed to its normal volume in the steamed state under ambient pressure. It is then lifted from conveyor belt **19** by conventional take-off devices (not shown.)

The duration of the steaming treatment in zone B is a function of the speed at which belts **16** and **19** are operated and which is held, for instance, in the case of zone B having the above-given dimensions, in a range of from 2 to 6 meters per hour.

The embodiment of an apparatus as shown in FIGURES 1 and 2 can also be modified by omitting conveyor belt **16** entirely. When this is done, the textile material will slide along the bottom wall of box **2** in direct contact therewith, each fold being pushed forward by conveyor belt **19**. It is then necessary that the overall friction coefficient between the surface of conveyor belt **19** and the textile material is greater than the friction coefficient between the material and the surface of the bottom wall of box **2**. Attainment of this end is assisted by providing conveyor belt **19** with ribs, point or other types of protrusions adapted to engage the textile material effectively in order to advance the textile material while at the same time the surface of the bottom wall of box **2** must be smooth. It can also be coated with a substance of especially low friction coefficient such as polytetrafluoroethylene.

However, passage of folded material through the channel constituted by zones A, B and C of the interspace between boxes **2** and **3** can be further greatly facilitated if the folds deposited on conveyor belt **19** are not tilted forward but backward so that they are pulled instead of pushed through that channel. For this purpose the apparatus is provided with a special feeding arrangement which is shown in FIGURE 3 and comprises an inclined plate **27** on which the folds **26** are initially deposited with the aid of folding device **25** and from where it slides down to a curved plate **28** the lower end of which is flush with the upper reach of conveyor belt **19**. When the folds deposited on plate **27** drop down onto curved plate **28** they are tipped over so that the top end of each fold as laid onto the plate **27** becomes its foot end on curved plate **28** and subsequently on the upper reach of conveyor belt **19**, while the initial foot end of each fold as deposited on plate **27** becomes its top end and is tilted backward relative to the foot end of the same fold.

This arrangement, moreover, affords an outstanding advantage in that, at the discharge end, the folds of the material are not withdrawn one from under the other as in the case of FIGURES 1 and 2 but rather they are arranged so as to be taken out by merely lifting them off belt **19**.

Another structural modification can consist in partitioning the box **2** and/or the box **3** into a plurality of compartments each fed with steam at different temperatures, for example at lower temperatures at the material feeding end, and at a higher temperature in the subsequent portion of the machine.

The preferred embodiment of the invention is illustrated in FIGURES 4 and 5 in which figures reference numeral **31** shows a schematically illustrated frame in which there is mounted a hollow drum **32** which replaces the upper box **2** of the preceding embodiment. This drum is rotatably mounted on a hollow shaft **33** through which steam is fed into the interior of the drum by way of perforations **34**, while water of condensation is drained off from the interior of drum **32** by way of a suction pipe **34***a*.

In frame **31** there is further mounted a tub-shaped box **35** which takes the place of the lower box in the embodiment shown in FIGURES 1 and 2. This box or "tub" **35** surrounds drum **32** in such a manner that the drum shaft **33** and the longitudinal central axis of the cylinder partially involved by the inner tub wall **36** are parallel but do not coincide. Rather, the curvature of the inner tub wall **36** as defined in a plane perpendicular to the drum shaft **33** is such that there is a wide gap between that inner surface and the cylindrical surface **32***a* of drum **32** near the upper tub rim **37**, the "tub" being tilted so that its rim **37***a* on the opposite side of drum **32** is lower. Drum shaft **33** is then so placed relative to the central longitudinal axis of the inner tub space that the drum surface **32***a* and the inner tub wall **36** are at a substantially constant minimum distance from each other over a zone extending to both sides of the lowermost point of drum **32** in tub **35** about an arc ranging preferably from 30 to 70°. In this zone the interspace between drum surface **32***a* and inner tub wall **36** is of a substantially constant minimum cross sectional area so that this zone B′ corresponds to zone B of the interspace between boxes **2** and **3** in the embodiment of FIGURES 1 and 2, while the portion of the interspace between the cylindrical surface of drum **32** and inner tub wall **36** above the aforesaid zone B′ on the side of the upper rim **37** of tub **35** corresponds to gradually narrowing entry zone A in the embodiment of FIGURES 1 and 2 and has therefore been designated as A′ and the zone of the aforesaid interspace above zone B′ on the side of lower tub rim **37***a* has been designated by C′ since it corresponds to zone C of the embodiment of FIGURES 1 and 2. The body of tub **35** is hollow and the tub can be heated by introducing steam into that hollow body through a pipe **38**, while water of condensation can be drained from the tub body through drain pipe **38***a*. Here also, if desired, the tub **35** could be partitioned into two or more compartments which are likewise heated with steam at different temperatures. For example, the left portion, as viewed in FIGURE 4, can be heated at a temperature lower than that of the other portion, in order to avoid a premature overheating of the ingredients incorporated in the material to be treated.

There is further provided a steam inlet tube **39** which is mounted in tub **35** to pass therethrough being hermetically sealed off from the interior of the hollow tub body, while opening into the interspace between the inner tub wall **36** and the cylindrical drum surface **32***a*. The opening of steam inlet pipe **39** is covered by a grid **39***a*. In the embodiment of FIGURES 4 and 5, the steam inlet pipe **39** opens at the lowermost point of the zone B′ but it could also open into that zone somewhat to the right or to the left thereof; also more than one steam inlet opening could be provided. It is also possible to mount drum shaft **33** at both ends in frame **31** in such a manner that its position relative to the inner tub wall **36** can be adjusted, whereby it becomes possible to vary the distance of drum surafce **32***a* from inner tub wall **36** and at the same time also the length of zone B′ in the direction of the movement of textile material therethrough. In practice, the minimum distance between drum surface **32***a* and inner tub wall **36** is, for example, adjusted to 4 cm.

The near-cylindrical space involved by the inner tub wall **36** is closed at both ends of the tub by end plates **40** and **41** which, in the preferred embodiment of FIGURES 4 and 5, are provided each with an opening **42** through which the end portions of drum **32** pass to the outside with sufficient play to permit free rotation of drum **32** in these openings. Plates **40** and **41** are adapted to fit snugly with their rim **42***a* into the curvature of inner tub wall **36** and are held in position therein by adjustable supports **43** which are schematically shown in FIGURE 5. The rims **42***a* of plates **40** and **41** need not be sealed tightly on inner tub wall **36** since sealing will be effected by the textile material being compressed in zone B′ in a similar manner as in zone B of the embodiment of FIGURES 1 and 2. Preferably, as illustrated in FIGURE 5, plates **40** and **41** are downwardly inwardly inclined so as to further decrease the cross sectional area of zone B′ by providing for a certain lateral compression of the textile material passing through that zone.

On drum surface **32***a* there are preferably provided projections such as ribs or points, interrupted ribs **44** being shown in the preferred embodiment of FIGURES 4 and 5. These ribs assist somewhat in moving material through zone A′ into zone B′ and assist in the latter zone in effecting a satisfactory seal against undesirable loss of steam from zone B′. As is shown in FIGURE 4 this is achieved by ribs **44** pressing on a plurality of fold layers and compressing them in cooperation with inner tub wall **36**. It is of special advantage that a plurality of fold layers and not only a single fold layer are always compressed between the ribs **44** and the inner tub wall **36**. This greatly enhances the sealing effect while at the same time avoiding the formation of stripes in the steamed material, especially when such material has been previously pad dyed.

The feeding of textile material which is for instance delivered from a pad mangle schematically shown at **45** via a turnstile type conveying roller **46** is effected by a fold-forming device **47** which carries out a pendular motion as indicated by arrows in FIGURE 4 and at the same time a reciprocating motion as indicated by arrows in FIGURE 5. This device **47** deposits continuously a sequence of folds **48** of textile material on a first conveyor belt **50** from the upper reach of which the folds drop onto a second conveyor belt **51** which takes the place of curved plate **28** in the feeding device shown in FIGURE 3 whereby the folds formed on conveyor belt **50** are tipped over in the same manner as are the folds formed initially on plate **27** when dropping onto curved plate **28** (FIGURE 3). The folded material is thus delivered from conveyor belt **51**, which is preferably operated at a higher speed than conveyor belt **50**, into zone A′ of the interspace between rotating drum surface **32***a* and the stationary inner tub wall **36** in such a manner that the foot end of each fold rests on the drum surface **32***a* while its top end is tilted rearwardly relative to such foot end. Thereby the folds are not pushed but pulled into the interspace as it narrows in zone A′ and merges into zone B′ in which the folds are subjected to maximum pressure.

Moreover, due to this feeding procedure, the steamed folds emerging from zone B′ and being decompressed in zone C′ are delivered past the lower tub rim **37***a* onto a table **52** in such position that each fold can be lifted off by a conventional take-off device (not shown) without having to be pulled from under a stack of superimposed folds and thus with a minimum of mechanical stress.

In practical operation the drum must be operated at such speed that the time in which each part of the continuous web or mat of the material is compressed and steam treated in zone B′ is sufficient to achieve a full effect. For instance, when applying the steam treatment to texile fibers in order to fix thereon or develop therein dyestuff continuously applied thereto in a pad mangle, then it is recommended to operate the drum at a speed corresponding to one drum revolution every 30 to 90 minutes depending on the drum diameter, so that the actual treatment time in zone B′, depending on the kind of material being treated, is that recommended hereinbefore. The penetration of steam into the material, the decrease in pressure caused therein and the avoidance of undue steam losses therein are the same as described in connection with FIGURES 1 and 2.

On completion of its travel, the material is expanded only slightly, at the outset, in the gradually broadening zone C′ of the interspace between drum surface **32***a* and inner tub wall **36**, and then the material is freely expanded when emerging therefrom. It is lifted from table **52** by appropriate drawing device (not shown) at the same speed at which it had been fed into zone A′.

An installation as described in the foregoing has proven capable of treating polyester fiber materials impregnated with dyestuffs, even when no dyestuff carrier at all was used.

In order to further illustrate such use of the apparatus there are a few non-limitative examples given below of dyeing operations, carried out with steaming in an apparatus of the kind described above.

Example 1

20 g. of Setacyl Blue P-RS (C.I. Disperse Blue 19, C.I. 61,110) are slurried in a hot mixture comprising 200 ml. of a 2% (solution of locust bean flour and 5 g. of diethanolamide of coconut oil fatty acid in 500 ml. of water.

To this mixture there is added a slurry of 20 g. of o-phenylphenol (as carrier) in 500 ml. of hot water. This liquor is used to impregnate a Terylene tow which is then squeezed to a bath content of about 50% and steamed with saturated steam at 2.6 atmospheres (corresponding to a temperature of about 140° C.) for 20 min.

The material is then washed in an aqueous solution containing 4 g. of NaOH and 2 g. of $NaHSO_3$ per liter at 90° C. to remove the o-phenylphenol and any residual unfixed dyestuff.

The material is rinsed and dried. A blue tow is obtained, which is evenly dyed and has a good, deep color penetration rating.

Example 2

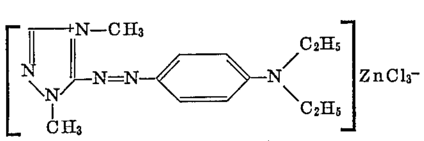
By using the same procedure as in the preceding example, but without using any carrier, and operating as outlined above, an equal dyeing effect is surprisingly obtained, with satisfactory evenness and depth of penetration, just as in the previous example.

Example 3

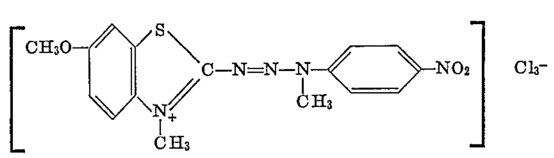
By using, instead of the Terylene tow, a combed Terylene top, and operating in the same way as in the previous example, a top is obtained, which is dyed uniformely and with good depth of penetration.

Example 4

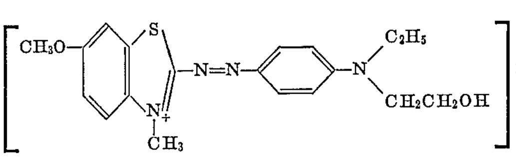
19.2 g. of the red dyestuff of the formula



6.2 g. of the yellow dyestuff of the formula



and 5.3 g. of the blue dyestuff of the formula



are pasted with 80 ml. of cold 60% acetic acid, and 200 ml. of hot water are added thereto.

40 g. of a dye assistant composition consisting of 35 parts of N-methyl-N,N-bis-(β-hydroxyethyl)-ammonium salt of coconut oil fatty acid, 35 parts of dodecyl alcohol pentaglycol ether and 30 parts of coconut oil fatty acid N,N-bis-(β-hydroxyethyl)-amide, as well as 100 ml. of a galactomannan thickener prepared by pasting 4 g. of galactomannan with 20 ml. of ethanol and adding thereto 200 ml. of hot water, are admixed with the dye paste, the whole is made up to 1 liter with water and the impregnation liquor thus prepared is brought to a temperature of 30–40°. The pH of this liquor is about 3.5–4.0.

Polyacrylonitrile tow is impregnated with this liquor, the fibers are squeezed off to a liquor content of 50%, calculated on the dry weight of the fibers, and steamed for 10 minutes with saturated steam at 105° under a relative pressure of 0.3 atmosphere.

The dyed goods are then rinsed several times with 45° warm water and treated with an aqueous solution containing 4 g. per liter of an antistatic and 2 g. per liter of a fabric softener.

Excellently level, deep bluish red fibers are obtained.

Example 5

37.5 parts of the chromium-containing monoazo dyestuff: 2-carboxy - 1 - aminobenzene→1-phenyl-3-methylpyrazolone (dyestuff:chromium=2:1), and 14.0 parts of the chromium-containing monoazo dyestuff:2-aminophenol-4-sulphonic acid methylamide→1-carboethoxyamino-7-hydroxynaphthalene (dyestuff:chromium=2:1) are dissolved in an 80° warm mixture containing 300 parts of a 2% aqueous sodium alginate solution and 10 parts of a mixture of 1 part of N-methyl-N-(β-hydroxyethyl)-amine salt of coconut oil fatty acid and 1 part of the condensation product of 1 mol of dodecyl alcohol and 7 mols of ethylene oxide, and 290 parts of water, and the solution obtained is diluted with cold water to 1000 parts. The temperature is then about 40°.

Nylon tops are impregnated with this liquor, squeezed to a liquor content of 50% of the weight of the fibers, steamed for 10 minutes at a temperature of 120° and then rinsed first with boiling water and then with cold water.

Olive-green nylon tops are obtained, having a deep, very level dyeing.

I claim:

1. An apparatus for the continuous steaming of textile fiber materials, comprising:

an upper container part of the surface of which constitutes an elongated bottom wall,

a lower container part of the surface of which constitutes an elongated top wall,

said upper and lower containers being so arranged relative to each other that the central longitudinal axes of said bottom wall and said top wall are in the same plane, and that a free passage is left between said bottom wall of said upper container and said top wall of said lower container,

elongated plates extending along both sides of said passage to form side walls thereof limiting the lateral extension of said passage to within the transverse widths of said bottom and top walls, and leaving an open entry and an open exit of said passage,

conveying means adapted for conveying a mass of textile fiber material through said passage from the enry to the exit opening of the latter,

feeding means adapted for feeding textile fiber material to the entry of said passage,

discharge means adapted for withdrawing said mass of fiber material from the exit of said passage,

means for heating said bottom wall of said upper container or said top wall of said lower container or both said walls,

steam introducing means adapted for introducing live steam under pressure directly into the central region of said passage,

at least one of said bottom wall, top wall and two side walls being so shaped that the cross sectional area of said passage decreases gradually to a minimum in a first region extending from said passage entry in the direction toward the central region of said passage, remains substantially constant throughout the central region of said passage and increases in a third region extending from the end of said central region to the exit of said passage, whereby said mass of material being conveyed through said passage is being gradually increasingly compressed in said first region, and is maintained at maximal compression throughout said central region, while being gradually decompressed in said third region, so that substantially tight sealing of said mass against said top and bottom walls and said side walls is achieved, so that losses of steam from said central region are essentially avoided and a substantial excess pressure above ambient pressure can be maintained in the latter region.

2. An apparatus as described in claim **1**, wherein the width of said elongated top wall of said lower container is about equal to or slightly larger than the width of said elongated bottom wall of said upper container.

3. An apparatus as described in claim **2**, wherein the length of said elongated top wall of said lower container is longer than and extends at both ends beyond the ends of, said bottom wall of said upper container.

4. An apparatus as described in claim **3**, wherein said upper and lower walls are substantially planar and are converging from the ends of said upper and lower containers at the entry side of said passage, while remaining substantially parallel to each other throughout said central passage region, and diverging from each other from the end of said central region towards the ends of said upper and lower containers at the exit side of said passage.

5. An apparatus as described in claim **3**, wherein said side walls are substantially planar and converge toward each other from the entry of said passage toward the central passage region, while remaining substantially parallel with each other throughout said central region and diverging from each other from the end of said central region toward the exit of said passage.

6. An apparatus as described in claim **2**, wherein said upper and lower walls are substantilaly planar and are converging from the ends of said upper and lower containers at the entry side of said passage, while remaining substantially parallel to each other throughout said central passage region, and diverging from each other from the end of said central region toward the ends of said upper and lower containers at the exit side of said passage, and wherein said side walls are substantially planar and converge toward each other from the entry of said passage toward the central passage region, while remaining substantially parallel with each other throughout said central region and diverging from each other from the end of said central region toward the exit of said passage.

7. An apparatus as described in claim **4**, wherein said conveying means comprises a first conveyor belt associated with said lower container and mounted on the latter for movement along the top wall of said lower container from the entry to the exit of said passage, and means for driving said first conveyor belt in the direction from the entry to the exit of said passage through the latter.

8. An apparatus as described in claim **7**, wherein said side walls are mounted on said lower container in such a manner as to extend with their lower rims above said first conveyor belt with sufficient play to permit unimpeded operation of the latter.

9. An apparatus as described in claim **8**, wherein the gap between said lower side wall rims and the upper surface of said conveyor belt is narrow enough to permit tight sealing of said gap by the textile material conveyed on said belt when said material is compressed in the central region of said passage, thereby preventing substantial loss of steam from said central region.

10. An apparatus as described in claim **7**, wherein said conveying means further comprises a second conveyor belt associated with said upper container and mounted on the latter for movement along the bottom wall thereof from the entry to the exit of said passage, and means for driving said second conveyor belt in the direction from the entry to the exit of said passage through the latter in unison with said first conveyor belt.

11. An apparatus as described in claim **7**, wherein said feeding means is adapted for laying said fiber material in a sequence of folds on to said first conveyor belt.

12. An apparatus as described in claim **11**, wherein said feeding means further comprises means for placing said folds on said conveyor belt in such a manner that the top end of each fold is tipped rearward relative to its foot end whereby said conveyor belt pulls each fold by its foot end through said passage.

13. An apparatus as described in claim **5**, wherein said upper container is a rotatable cylindrical drum and said lower container is tub-shaped and surrounds said drum at the bottom and on both sides of the cylindrical drum surface, the central longitudinal axis of the top wall of said tub-shaped lower container extending in the central plane perpendicular to the drum axis, and having a curvature such that said central passage region extends about the lowermost zone between said drum and the top wall of said tub-shaped lower container.

14. An apparatus as described in claim **13**, wherein said conveying means comprises projections on the drum surface sufficiently short to leave adequate space for several layers of folded material in compressed state in said lowermost zone, and means for rotating said drum.

15. An apparatus as described in claim **14**, wherein said feeding means comprises means for introducing said fiber material in the form of a sequence of folds several of which are always partly superimposed upon each other into the passage between said drum and the top wall of said tub-shaped container at the entry opening of said passage, from which opening the projections on said drum are moved during rotation of said drum toward said lowermost zone and further from there toward the exit of said passage on the opposite side of the cylindrical drum surface.

16. An apparatus as described in claim **15**, wherein said feeding means further comprises means for tilting the folds of said material in such a manner that each fold end coming into contact with said top wall of said tub-shaped container is tipped rearward relative to the opposite end of the same fold which comes into contact with the cylindrical surface of said drum, whereby the latter surface in cooperation with said projections thereon pulls said folds through said passage.

17. An apparatus as described in claim **13**, wherein said steam introducing means is mounted in said tub-shaped container and opens into said passage in said lowermost zone.

18. An apparatus as described in claim **16**, wherein said discharge means comprises means for tilting the folds emerging from said passage exit in such a manner that the end of each fold which was in contact with said drum surface is tipped rearward of the opposite end of the same fold, which was in contact with the top surface of said tub-shaped container, whereby removal of the folds from the apparatus is facilitated.

19. A process for continuously treating textile fiber material with steam under pressure, comprising introducing a mass of textile fiber material into a first zone wherein said mass is gradually increasingly compressed to a maximum compression, passing the compressed material through a second zone in which its compression is maintained substantially constant and wherein saturated steam is introduced under a pressure above ambient pressure, and then gradually decompressing the steamed material in a third zone.

20. A process as defined in claim **19**, wherein the textile material is selected from natural polyamide fibers, synthetic polyamide fibers, polyester fibers, polyolefin fibers, polyurethane fibers, and polyacrylonitrile fibers.

21. A process as defined in claim **20**, wherein the textile material is polyester tow laid in a sequence of folds several of which are always superimposed upon one another.

22. A process as defined in claim **20**, wherein said textile material consists of polyester fibers and wherein the material passes through said second zone and is steamed therein for about 20 to 60 minutes.

23. A process as defined in claim **19**, wherein said textile material consists of nylon fibers and wherein the material passes through said second zone and is steamed therein for from about 10 to 20 minutes.

24. A process as defined in claim **20**, wherein said textile material consists of polyacrylonitrile fibers and wherein the material passes through said second zone and is steamed therein for about 10 to 40 minutes.

25. A process as defined in claim **22**, wherein the material while passing through said second zone is heated to about 120 to 140° C.

26. A process as defined in claim **23**, wherein the material while passing through said second zone is heated to about 120° C.

27. A process as defined in claim **24**, wherein the material while passing through said second zone is heated to about 105° C.

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