March 22, 1966 MASAHIDE YAZAWA 3,241,343

APPARATUS FOR CONTINUOUS HIGH SPEED AND UNIFORM PROCESSING OF FIBER MATERIAL

Filed Aug. 28, 1962 2 Sheets-Sheet 1

Fig. 1

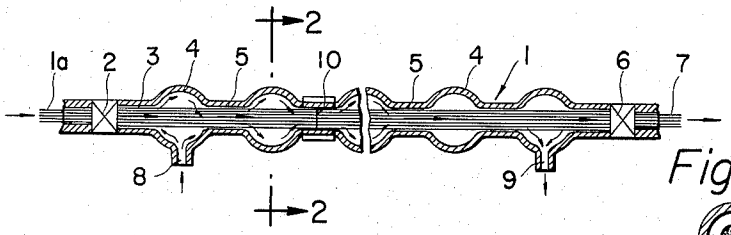


Fig. 2

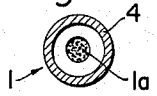


Fig. 3

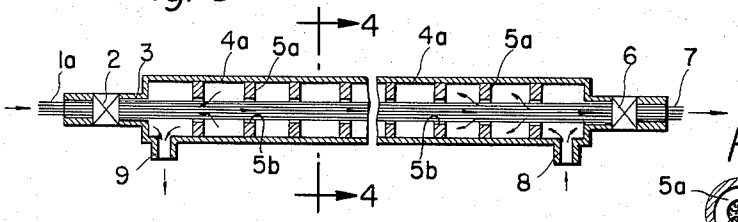


Fig. 4



Fig. 5

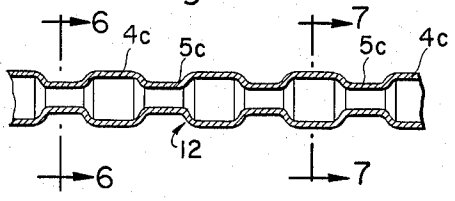


Fig. 6

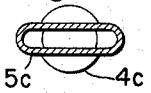


Fig. 7

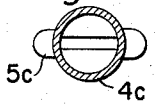


Fig. 8

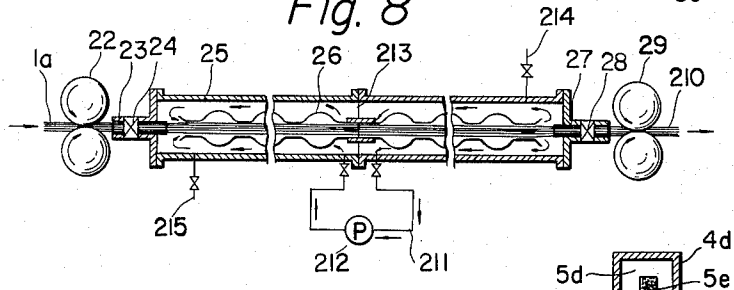


Fig. 9

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APPARATUS FOR CONTINUOUS HIGH SPEED AND UNIFORM PROCESSING OF FIBER MATERIAL

Filed Aug. 28, 1962 2 Sheets-Sheet 2

Fig. 10

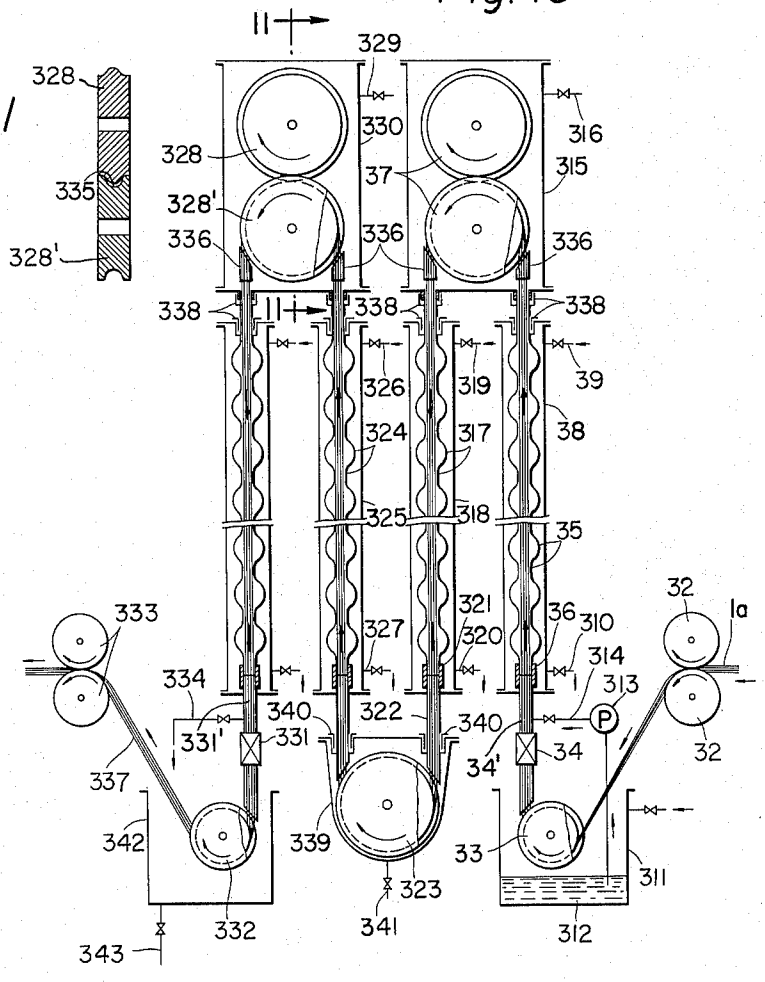


Fig. 11

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3,241,343

APPARATUS FOR CONTINUOUS HIGH SPEED AND UNIFORM PROCESSING OF FIBER MATERIAL

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Filed Aug. 28, 1962, Ser. No. 219,981
2 Claims. (Cl. 68—5)

The invention relates to apparatus for the continuous, speedy and uniform processing of elongated textile material. As to the material, bundles of warps drawn simultaneously in order from a plurality of spools on a creel, those wound on a warping beam, tows of spun artificial fiber, bundled slivers obtained in short fiber spinning process and specially processed to a continuous state, and the like, intermediate as well as thread products, can be used. By the term "processing" as used throughout the specification is meant any one or any selected combination of: refining; scouring; bleaching; dyeing; washing; recovery of chemicals; sizing; drying; heat treating; steaming and the like.

The main object of the present invention in its broadest aspect is to provide an apparatus adapted to carry out the above-mentioned continuous processing in a uniform, quick and efficient manner by forced stream of the processing liquid at high temperature and high pressure during processing. For instance, the apparatus according to the invention may operate at a temperature of 100° C. and higher under pressure.

For the realization of the above object, the apparatus according to the invention comprises mainly one or more processing tubes, through which the elongated textile bundles while under mechanical tension are continuously passed and subjected to the desired processing therein under pressure and sealed from outer atmosphere. According to the main feature of the invention, the processing tube is fabricated to have numerous reduced cross-sectional tube sections, for instance by squeezing the tube to one and the same degree at a plurality of positions, preferably evenly spaced. By the provision of many such regularly spaced reduced tube sections, the apparatus provides a set-up for frequent and positive take up of the processing fluid by the textile material and the corresponding release thereof from the latter while processing in the tube, and these processing actions may be repeated many times in an amazingly short time, so that in consequence the desired even and quick treatment can be finished at an amazingly high operating efficiency and with use of an extremely compact device, advantages not yet realized in the conventional art.

Other and more specific objects, features and advantages of the invention will appear from the detailed description given below, taken in conjunction with the accompanying drawings illustrating by way of example several preferred embodiments of this invention.

In the drawing, FIG. 1 is a longitudinal section through a horizontal type one stage processing apparatus and a somewhat modified form thereof, both embodying the principles of the invention, wherein the processing fluid is supplied under pressurized conditions;

FIGURE 2 is a transverse section taken in a plane identified by line **2**—**2**, FIGURE 1;

FIGURE 3 is a longitudinal section corresponding to FIGURE 1, but showing a modified form of one-stage processing apparatus;

FIGURE 4 is a transverse section taken in a plane identified by line **4**—**4**, FIGURE 3;

FIGURE 5 is a diagrammatic view illustrative of still another form of the processing tube;

FIGURE 6 is a transverse section taken in a plane identified by line **6**—**6**, FIGURE 5;

FIGURE 7 is a transverse section taken in a plane identified by line **7**—**7**, FIGURE 5;

FIGURE 8 is a longitudinal section of a modified embodiment of the invention provided with a closed circulation of liquid under pressurized conditions;

FIGURE 9 is a transverse section of a square processing tube;

FIGURE 10 is a longitudinal section through a vertical multi-stage apparatus employing a series of processing tubes under pressurized conditions, in which processing liquid is entrained with the bundles and exhausted out at the end of the tube; and

FIGURE 11 is a central vertical section through one pair of pinch rolls, taken in a plane identified by line **11**—**11**, FIGURE 10.

Referring to the drawings, especially FIG. 1 thereof, textile bundle **1***a* is pased through a valve **2** of a processing tube or an elongated autoclave **3** into the interior thereof, said valve serving to check possible leakage of a fluid circulating through the tube as will be described more in detail hereinbelow. The tube **3** is of varying cross-section as shown. More specifically, the tube comprises an alternate arrangement of enlarged sections **4** and reduced sections **5**. Thus, it will be noted that the velocity of the fluid or processing liquor flowing through the processing tube varies throughout the tube, and is accompanied by an intense turbulence. With such arrangement, the contact of the bundles with the processing liquor is frequently altered and the treatment or processing of the textile bundles can be made extremely uniform. The textile bundle **1***a*, which is led forcibly under mechanical tensions, travels through valve **2**, which prevents almost all leakage of the pressurized liquor, and is introduced into processing tube **3**, which is sealed from the atmosphere. The processing tube comprises a plurality of sections of alternately large diameter **4** and small diameter **5**.

The adequately and evenly treated material is then taken out of the processing tube at the opposite end thereof through a further pressure sealing valve **6** and in the form of processed bundle **7**, whereby the valve serves again to minimize the possible leakage of the fluid out of the tube. For the purpose of circulation of the treating liquid through the tube and in the same flow principle, as indicated in FIG. 1, a liquid supply pipe **8** is connected to the processing tube at a point near the inlet end thereof, while a discharge pipe **9** is connected with the said tube in the neighborhood of the outlet end thereof. In the same figure, a number of small arrows are shown so as to illustrate the advancing direction of the processing and processed material and the direction of flow of the treating fluid. In this arrangement, a joint **10** for the tube **3** is provided for ease in manufacture thereof. It will be clear that the number of such joints may be increased as desired in accordance with the size of the arrangement as a whole. When the processing tube is made of glass, the joint may be of Teflon, rubber or a similar resilient and tough material. It will be further clear that the length, pitch and the cross-section of the reduced tube section may be suitably dimensioned as occasion may desire.

The valves **2** and **6**, previously identified, as well as valves **24** and **28**, FIGURE 8, and **34** and **331**, FIGURE 10, may be as disclosed in my U.S. Patent Number 2,954,687, October 4, 1960.

A somewhat modified embodiment of the invention shown in FIG. 3 is constructed to operate based upon the counter-flow principle. In this arrangement, a cylindrical tube **4***a* has fixed therein a number of spaced separating walls **5***a* having reduced openings **5***b* for passage of the textile bundles to be treated. However, the cross-section

of the processing tube may be square or rectangular as shown at 4*d*, FIGURE 9, and spaced square or rectangular partition walls 5*d* with square central openings 5*e*. If the thickness of the separating wall such as 5*a* or 5*d* is increased considerably, it will produce effects similar to those produced by the elongated reduced wall section in the first embodiment.

Another modification is shown in FIG. 5, wherein tube 12 can be produced from a cylindrical glass tube by squeezing it while in a hot state at a plurality of spaced positions from the opposite sides of the tube stock. As shown, the squeezed portions 5*c* are each shaped into an elliptical cross-section while the non-processed portions of the tube retain their original circular cross-section as at 4*c*. It will be clear that both kinds of tube portions thus produced have unequal sectional areas, yet an equal peripheral length. The squeezed tube portions have naturally a smaller cross-section than that of the non-squeezed portions.

As for the cross-section of the processing tube, any configuration or any combination of sectional configurations may be employed. For instance, the reduced tube section may be round, elliptical, rectangular, square, rounded rectangular, rounded square, elongated plate-like and others. Similarly, the large area tube section may be fabricated into any desired shape. Any combination of various shapes of the two kinds of tube sections may thus be employed when it is required to meet specific processing demands.

As the material of the tube stock, glass is highly recommended for the reason that a glass tube has a smooth inside surface and it can conveniently be made into tube elements of any desired variable diameter or as a continuous tube of such a nature. According to the circumstances, however, any selected metal or plastics may be employed as tube stock material, especially for obtaining more strong and tough processing tubes.

When the processing fluid is caused to flow in the same direction as that of the textile bundles to be processed, the resistance met by the latter in passing through the tube will be much reduced since passage is assisted by the flow of the liquor and thus the tension in the bundles will be reduced accordingly. In the case of recovering chemicals deposited on or in the textile bundles or in the washing of such bundles, it is advisable to direct the flow of liquor counter to the direction of the bundle flow in order to increase the efficiency of the treatment.

The ratio of the cross-section of the treating bundles to that of the processing tube may vary according to the kind of treatment. When 30–40% of the cross-section of the reduced tube section is occupied by the bundles being treated and the rest is filled with the liquor, the resistance of the bundles to passage through the reduced tube sections is relatively large; this, however, does not lead to any damage of the textile material.

With an occupying ratio of 30–40% as above mentioned, the surface of the fibers acts as a frictional surface for checking possible through-flow of the processing fluid, thus, the pressure is cut in proportion to the fiber density within the tube in case of treatment by liquid, or in case of processing by a gaseous medium. More specifically, a fiber density as above specified may preferably be employed at the inlet nozzle for introducing the textile material into the processing tube. On the other hand, the fiber density of textile bundles within the interior of the tube may vary considerably according to the kind and conditions of the processing. For instance, in the case of dry processing, wherein the processing medium is mostly a hot air stream, a relatively low fiber density within the tube is employed for minimizing possible pressure loss. As an example, about 1/30–1/20 mm.^{2} per denier, or about 3–5 mm.^{2} per thread of 100 denier at the reduced tube section is recommended.

The individual threads while being so treated may flutter in every direction under the influence of the hot air streams so far as the limits of the tube allows them to do so. Thus, each thread in the bundle is dried while being subjected to repeated contact with and separation from the neighboring threads. When the threads are given a viscous liquor in the end period of the processing, for instance, in the case of resin finishing, sizing or the like, they complete the drying in the above mentioned manner, while they are kept fluttering in the circulating hot air streams, so that the bundles can be treated as a whole in comparison with the stationary drying process, and the individual threads are kept separate, or in such a state that they are not liable to stick together strongly and, accordingly, can be easily separated when dry. Thus, with use of a plurality of the novel arrangements each constructed according to the invention, warps on a beam, for instance, can be treated continuously in a series of successive treating stages for degumming, bleaching, dyeing, washing, resin-processing, sizing, drying and the like, which fact is also an outstanding feature of the invention.

Except in the case of viscous fluid processing, as above mentioned, the drying process of the textile bundles can be carried out without hindrance on any suitable one of conventional driers.

In the foregoing, it has been described that the fiber density relative to the cross-section of the processing tube may vary considerably depending upon the kind and nature of the processing. In practice, for instance, when textile bundles comprising 1000 warps of 100 deniers, thus amounting as a whole to 100,000 deniers, are processed, the diameter of reduced sections of the processing tube will amount to 5–6 mm. and the same of regular or large tube sections may be of any suitable size, among others 10–15 mm. in case of a pad dyeing process with a minimum bath ratio as above specified. In the case of drying process, however, the diameter of the reduced tube sections may be about 70–100 mm. under the similar warp thread conditions. With the same overall denier number of the textile bundles, the optimum size of the reduced tube section may be subject to alteration within those specified above, depending upon the kind and nature of the textile elements, such as filament yarns or spun yarns. The above size may be further subject to modification for tows when employed, according to the kind and nature of the fiber, with or without crimps thereof.

The smaller the diameter of the reduced or squeezed tube sections, the shorter the pitch thereof may be. For instance, for processing the above mentioned textile bundles comprising 1000 warps, a processing tube may comprise about thirty reduced sections per meter and when these bundles are processed at a rate of 10 m. per minute with use of a tube length of 10 m., there will be 300 renewal contacts of the processing liquor per minute with the textile material, so that a quick, uniform and effective processing may be carried into effect in an amazingly short processing period.

Commercial tows of various artificial fibers are of 200,000–500,000 deniers, so that the diameters of the reduced and large tube sections may be about 8–20 and about 15–30 mm., respectively. Thus, there will be about 20 abrupt alterations in the tube cross-section per 1 m. length, and uniform processing with safety can be expected under these conditions.

FIG. 8 illustrates a horizontal type processing arrangement, wherein textile bundles are passed through a processing tube and a pressurized high temperature fluid medium is circulated through the interior of the tube for processing. Referring to the figure, textile bundles 1*a* are fed by a couple of feed rolls 22 through inlet tube 23 and valve 24 providing for cutting off loss of pressure, into a continuous processing tube 26 having a series of spaced and reduced tube sections as fully described in connection with FIGS. 1 through 7. The tube 26 may be fabricated from a tubular heat-resistant glass stock as before, and is mounted in a pressure shell or jacket 25,

The processed textile bundle designated by **210** in the figure is taken out through pressure reducing outlet tube **27** and valve **28** into the open ambient atmosphere by the action of a couple of delivery rolls **29**. The processing medium flows through the tube in the same direction as that of the advancing textile material and separates at the delivery end of shell **25** from the processed material. The fluid medium flows then through the intermediate space between the tube and the shell in the opposite direction toward the central portion of the latter, through suction pipe **211**, impelled by a pump **212** and is delivered again to the shell for recirculation. The processing medium thus supplied to the leading half of shell **25** is introduced at the inlet end into the processing tube together with the textile material to be produced and recirculates through the tube. This processing and recirculating process will be clearly understood with reference to the number of small arrows shown in the figure. For better recirculation of the processing medium, there is provided a separating wall **213** at the center of the shell, which wall separates the interior of the shell into two end-to-end compartments as shown. The connection of the delivery pipe of the liquid circulating pump opens into the left-hand compartment of the shell and that of the suction pipe **211** opens into the opposite or right-hand compartment. A liquid make-up pipe **214** and a drain pipe **215** are connected at suitable points with the interior of the shell **25**, which may, if necessary, be fitted with a heating jacket, not shown.

With use of the processing arrangement shown in FIG. 8, the take-up velocity of rolls **29** may be adjusted appropriately so as to be less than that of the delivery rolls **22** thereby allowing the textile material to slacken and, thus, to shrink while being processed. On the contrary, if the take-up rolls **29** are driven at a slightly higher velocity than the feed rolls **22**, the textile bundles are drafted or tensioned in a corresponding degree.

When the shell **25** in the above arrangement is made in the form of a metallic pressure vessel and the processing tube **26** is fabricated from a heat resistant glass stock, the thus obtained device can be effectively and safely utilized for the desired pressurized high temperature processing purpose, because the internal pressure acting upon the inside wall surface is only the circulating pressure of the processing medium which amounts to a relatively small value. If necessary, the processing tube may be fabricated from metal stock as already explained.

In the apparatus of FIG. 8, the processing liquid is used in a closed circulation system, and the liquid, which acts effectively on the bundles already processed, comes out into the atmosphere entrained with the bundles included therein; therefore, a weak point of this embodiment is that it requires a process for recovering the liquid, if the wasting of the liquid is an important economic factor. Therefore, the apparatus of FIGS. 10 and 11 described hereinafter is generally used for dyeing, bleaching, and handling with chemicals except for extending of synthetic fibers with hot water, loosening with hot water or steaming with saturated steam, drying with hot blast. In the apparatus of FIG. 8, care must be taken, if the production of faulty products is to be prevented, to wait until an equilibrium is obtained between the outflow entrained with the bundles and the processing liquor supplied at the start of the process. It is also disadvantageous when circulating liquid is left over after the processing has been completed.

FIG. 10 illustrates a vertical multi-tube type arrangement for continuously processing textile bundles for the purpose of degumming, bleaching, dyeing and the like with use of a small bath ratio, generally amounting to several integers or less, and under the influence of steam heating in pressurized conditions.

More specifically, textile bundle **1***a* is fed from feed rolls **32** beneath and upwardly about a guide roll **33**, a pressure-cutting metallic inlet tube **34'** and a valve **34** into a variable cross-sectional processing tube **35** made of glass and fabricated in the similar way as was described in connection with FIGS. 1 to 7. A couple of pinch rolls **37** are mounted above and in proximity to the upper end of processing tube **35** for take-up of the thus processed bundles and for feeding them into the next processing stage.

A coupling **36** is provided in the above described first processing stage for providing an effective sealing connection between the metallic tube **34'** and the glass processing tube **35**, which is mounted in a pressure shell or jacket **38**. Steam of a proper processing temperature is supplied through a supply pipe **39** into the interior of the shell and heats indirectly the textile bundles and the processing liquid, both passing through the interior thereof. The developed condensate is drained off from the shell through a drain pipe **310**. If the guide roll **33** is kept in a submerged condition below the level of the processing liquid bath **312** contained in a tank **311**, the traveling textile bundles while passing therethrough will take up more than enough of the liquid and the surplus will be removed at the entrance of inlet tube **34**. In this way, a proper quantity of processing liquid is taken up by these bundles and carried along thereby at a substantially constant rate into the processing tube. On the contrary, if the guide roll **33** is kept high above the liquid level in tank **311**, the processing liquid is pumped under pressure by means of a metering pump **313** through a supply pipe **314** into the interior of the processing tube at a properly selected bath rate relative to the passing velocity of the textile material to be processed. It is easy in this case to regulate the operation of the pump so as to obtain substantially the same flow rate of the liquid within the processing tube as the traveling velocity of the material. Steam supply pipe **316** is connected within chamber **315**, in which said couple of pinch rolls are journaled, so as to supply steam at a proper rate and thus to heat up the processed bundles together with the take-up liquid delivered from the first processing stage. In this way, heat lost during the first processing can be made up, if necessary. With such arrangement for direct steaming, the condensate may dilute processing liquid and, under some conditions, affect to some extent the processing desired. When it is desired to eliminate such a disadvantage, the steam supply from the pipe **316** may be interrupted. Or instead, ample heating area for the indirect heating through the tube wall **35** may be provided. Since the upper or outlet end of the processing tube in the first stage opens into the interior of the said chamber **315**, the steam supplied from pipe **316** will flow in the counter-flow manner into the processing tube **35** at the outlet end thereof, when the liquid entrained by the textile bundles into the tube is relatively small so that the interior space thereof cannot be occupied by both the material and the liquid, thus providing possibilities of direct-heating part of the material within the tube and promoting the favorable uniform heating of the material while being processed.

When steam pressures in the two supply pipes **39** and **316** are made equal to each other, both the inside and the outside pressures of the tube will be equalized and possible breakage thereof may be effectively prevented, even when the tube is made of glass, and the high operating pressure can be borne by the outermost shell wall.

In the process in which the bundles and the processing liquid entrained with the bundles are forced into the processing tube and the pressure and the temperature therein are raised in predetermined values, there exists a pressure gradient between the inside of the processing tube and the atmosphere; therefore, part of the processing liquid and steam—that is, the processing fluid, whatever the proportion or ratio of liquid to entrained bundles, tends to leak out, and the flow of this leakage is toward the inlet of the processing tube, counter to the flow of the entrained bundles and accompanying processing liquid. This backflow also passes alternately through the en-

larged and smaller diameter sections of the processing tube, and the conflict between backflow and normal flow results in increased agitation which, in turn, results in more effective contact between the entrained bundles and the processing fluid. The result is higher efficiency—that is, more uniform processing in less time. This increase in agitation is greatest in the first processing tube **35** (FIGURE 10). At this point it is mainly the surface of the fibers that is affected. The agitation in the processing tubes following the first processing tube **35**, though not as vigorous, serves to prolong the processing and insures that the liquid penetrates uniformly and deeply into each fiber. This prolonged agitation is vitally important, since the processing liquid decreases in strength as it passes through the processing tubes, especially in passing through the first processing tube **35**.

The input of processing liquid at the inlet is adjusted to allow for the leakage mentioned above. If processing liquid is added beyond a certain rate the speed of flow of the processing liquid will be greater than that of the fiber bundles. In this case, since the flow of the liquid helps to carry the load, the amount of tension required to transport the bundles through the processing tube can be reduced. If the processing liquid is pumped into the inlet at a relatively low rate—for example, in a quantity 1–2 times the weight of the bundles or 0.8–1.5 times the weight of bundles which have absorbed processing liquid and been squeezed by means of rollers of dies—the processing tube will not be completely filled by the processing liquid and bundles. In this case, immediately after introducing the bundles into the processing tube, the blasting action caused by steam under pressure sets up the turbulence and agitation described above, with the result that some backflow and leakage occurs and the agitation extending throughout the processing tubes effects efficient and uniform processing. Therefore, it is not necessary to completely fill the processing tube with processing liquid to achieve uniform processing, provided that the sectional area of the small diameter sections is made small enough to effect, in conjunction with the sections of larger diameter, the necessary compression and decompression of the liquid which, in turn, effects the agitation necessary for effective contact of the liquid with the fibers. This refers to the specific embodiment made in accordance with FIG. 10 and operated as a pad-pressure steaming process.

The textile bundles delivered by the pinch rolls **37** are led along a passage turned about 180 degrees relative to the foregoing passage during the first stage and passed downwards through a second processing tube **317** constituting a second stage. This second tube **317** is also mounted in a pressure shell **318** and again heated indirectly from outside by steam supplied from a supply pipe **319** and the developed drain is carried away through discharge pipe **320**. The liquor squeezed out from the textile material by the action of pinch rolls **37** accumulates on the bottom of chamber **315** and is then taken up again by the material and carried into the second tube. At the lower or outlet end of the second processing tube **317**, there is provided a coupling **321** for effective connection of the glass tube with a metallic outlet tube **322**. The textile bundle with take-up liquor is turned after passage through the outlet tube again about 180 degrees by a positively driven guide roll **323** and led to travel along an upward vertical passage defined by a third processing tube **324**, which is again mounted in a metallic pressure shell **325** having a steam supply tube **326** connected thereto for heating up the tube. The condensate thus developed is carried away through a discharge pipe **327**. Above the outlet of the third processing tube, there is again provided a couple of pinch rolls **328**, which draw the processed textile against all the resistant forces while passing through the third processing stage including joint and inlet and outlet tubes as before. Steam supplied from steam pipe **329** heats up directly a chamber **330** containing the pinch rolls **328**. After passage between these rolls, the textile bundles are turned further about 180 degrees and guided so as to travel along a substantially vertical downward passage constituting a fourth processing stage, and so on. It will thus be seen that the textile bundles are driven at the bottom by the guide rolls and at the top by the pinch rolls, so that they may pass along a vertically arranged zig-zag passage including a series of processing stages during a predetermined time long enough to insure processing to the desired degree and while accompanying a proper quantity of the processing liquid as a whole. Finally, the processed bundles are passed through a pressure sealing outlet tube **331'** and a pressure cut-off valve **331**. The thus finally processed bundles are passed around a final guide roll **332**, caught by a couple of pinch rolls **333** and then delivered to a further processing machine not shown. The surplus processing liquid taken up by the bundles and checked by the final stage pressure cut-off valve **331** is taken out through a discharge pipe **334**.

At the guide rolls and pinch rolls above described, plain cylindrical rolls may be used. As shown upon FIGURE 11, however, rolls having peripheral grooves **335** of U- or V-section have been shown. Such rolls, if employed in combination with protecting tubes as shown in the respective pinch roll chambers **315** and **330** and with a further protecting tube **337** extending between final guide roll **332** and final pinch rolls **333**, will provide convenience in processing continuously two bundles with use of the present novel arrangement. There is always a gap between the protecting tube **336** and the related processing tube **35**, **317** or **324**, for discharge or introduction of the liquid from or into the processing tube, as the case may be, through the gap. When the textile bundles are of a continuous nature, as in the case of tow bundles, warp bundles or the like, these protectors can be dispensed with. Stuffing boxes **338** are provided at the upper end of the processing tube and between the latter and the related pinch roll chamber so as to seal-off the accumulated liquid on the bottom wall of the chamber and prevent from entering the intermediate space between the processing tube and the pressurized shell wall. In a similar way, stuffing boxes **340** are provided between the chamber **339** containing guide roll **323** and the material outlet and inlet tubes **322** for interrupting any liquid communication therebetween. At the starting of the machine, a warming-up operation is necessary as will be well understood by those skilled in the art. Drains as developed in the processing tubes while in such warming-up operation, can be discharged through drain outlet **341**.

After completion of the processing, the surplus or processed liquid is discharged from the final stage tube in the proximity of the outlet end thereof through a discharge pipe **334** into the tank **342**, then through a further discharge pipe **343** to some suitable place.

As previously explained, the pressure reducing valves to be employed in the present arrangement, may be those disclosed in Japanese Patent Nos. 192,052 and 198,429 and U.S. Patent 2,954,687.

As already explained, the textile bundles to be treated by the present invention may be 50,000–100,000 denier for warp bundles on a conventional beam; 200,000–500,000 denier for artificial fiber tows, and about 200,000–300,000 denier for such bundles as comprising 6–10 slivers as obtained in conventional short fiber spinning process; and the reduced tube sections have a diameter of 5–15 mm. and the regular or large tube sections may be of a diameter of 10–30 mm., and the pressure shell may be 30–50 mm. in its diameter. With these dimensions, the interior volume of the processing tube is amazingly small, so that it is safely used under high operating pressures and temperatures and its operating and production costs are extremely economical.

Example 1

A composite sliver, comprising three sliver elements, each being of 65,000 denier and comprised in turn of a number of 3 denier filaments made of commercial polyester fibers, 75 mm. long, was led through a processing tube apparatus shown in FIG. 10, having 30 reduced tube sections per meter. The inside diameter of each of the reduced sections was 7.5 mm. The composite sliver was given a preliminary treatment with a padding solution, containing a dispersing dyestuff such as Amakron L.S. 6%; Resolin blue TBL 2%; ethanol 10% and a proper penetrant 0.1%. The pickup ratio was 120%. The thus padded sliver was subjected in the processing apparatus, while continuously passing at a constant velocity of 12 m./min., to a hot pressurized treatment by a saturated steam of 160° C. for about 1 minute. In this processing, about ⅕ of the padded solution was squeezed out at the pressure cutting tube at the inlet of the apparatus by the inside pressurized medium from inside to outside, which surplus liquor was recovered in a suitable way, while the dyestuff of the entrained liquor by the sliver was completely deposited on and within the treated material fully to the core and without uneven dyeing. It was found that the finally entrained liquor by the products contained any appreciable amount of dyestuff and the products were completely dyed to a dark brown color.

Example 2

A tow, 450,000 denier, of commercial acrylic fiber was led through a processing tube having 25 separated and reduced tube sections per meter arranged substantially as shown in FIG. 10, which sections had, however, successively reduced inside diameters in the advancing direction of the tow from 12 to 11 mm. The inside volume of the tube as a whole amounted to about 2.0 times the processing fibrous material. A dyeing solution containing 1.5% of Anthrason blue FGL, a cationic dyestuff, adjusted by adding a proper quantity of acetic acid to pH 4, is recirculated by means of a metering pump at a ratio corresponding to 3.5 times the processing volume of the tow and under pressure, while a proper quantity of saturated steam of 130° C. was blown into. The tow was fed continuously at a constant velocity of 10 m. per minute and thus subjected to dyeing processing for about 1 minute under elevated temperature and pressurized conditions. About ⅓ of the supplied dyeing liquor leaked out from inside through the pressure cutting tube to outside at the inlet of the processing apparatus, which leakage was recovered in a proper way, while the dyestuff contained in the accompanying liquor by the introduced fibrous material was almost completely picked-up by the latter, thus providing evenly and completely dyed dark green products. It was found that the dyeing effect penetrated fully to the core of the processed fibrous material without representing uneven dyeing.

Example 3

A tow similar to that described in Example 2 was preliminarily padded with a 1% solution of sodium chlorite until the fibrous material picked up a 110% quantity of the liquor relative to the material. The padded material was then passed through the processing tube described in Example 2 and treated with a saturated steam of 135° C. The thus bleached material represented a pure white tone.

What is claimed is:

1. An apparatus for treating with fluid, an elongated bundle of textile fibers, four tubes each having an axis of symmetry and mounted with said axes in vertical, laterally spaced relation to form first and second pairs of tubes, each said tube having a plurality of constrictions spaced along its axis and expanding between each contiguous pair of constrictions to form an expansion chamber, four tubular jackets each surrounding and enclosing a respective one of said tubes in radially spaced relation therewith, a first guide roll below and tangential to the axis of the first tube of said first pair, means feeding said bundle downwardly to and upwardly into and through the first tube of said first pair, a first pair of pinch rolls above and feeding the bundle from the first into the second tube of said first pair, guide means feeding the bundle from exit at the lower end of the second tube of said first pair, upwardly into the first tube of said second pair, a second pair of pinch rolls above and feeding the bundle from the first to the second tube of said second pair, a second guide roll at and tangential to the axis of said second tube of said second pair and about which said bundle passes downwardly, then upwardly, and a tank in which said first guide roll is positioned and adapted to be filled with fluid for saturating said bundle in its passage about said first guide roll.

2. The apparatus of claim 1, and first and second pressure vessels each enclosing a pair of said pinch rolls, respectively, gland means in the bottom wall of each said vessel and through which said bundle passes to and from said pinch rolls and means to supply steam under pressure to said vessels.

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