Nov. 26, 1968 S. COHN ET AL 3,412,411

METHOD FOR DYEING TUBULAR KNIT MATERIAL

Filed Sept. 13, 1960 3 Sheets-Sheet 1

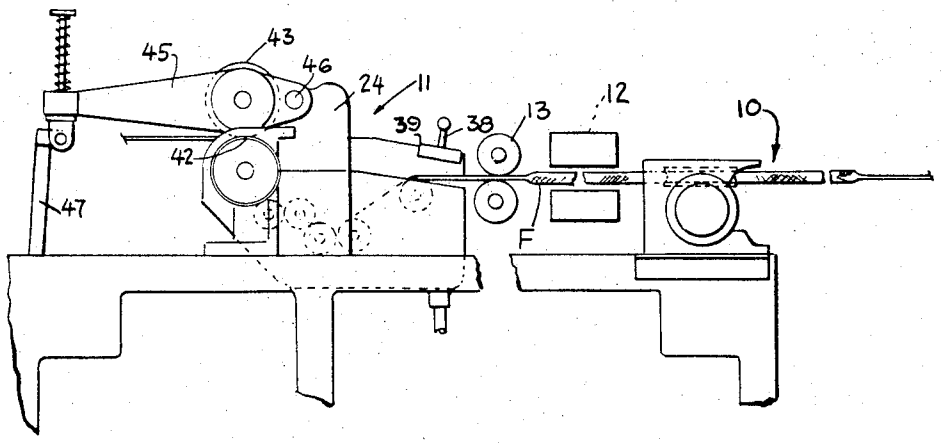

Fig. 1

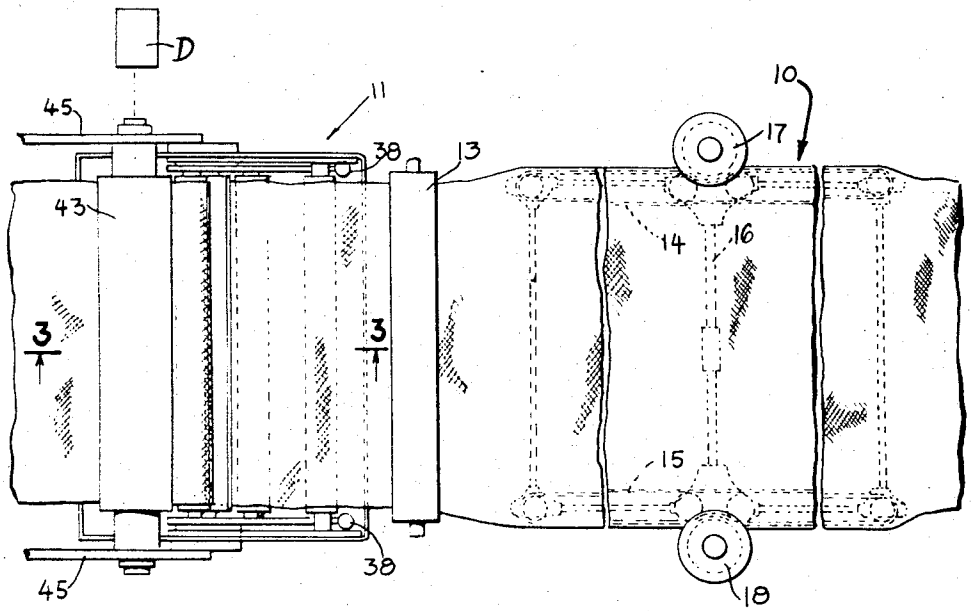

Fig. 2

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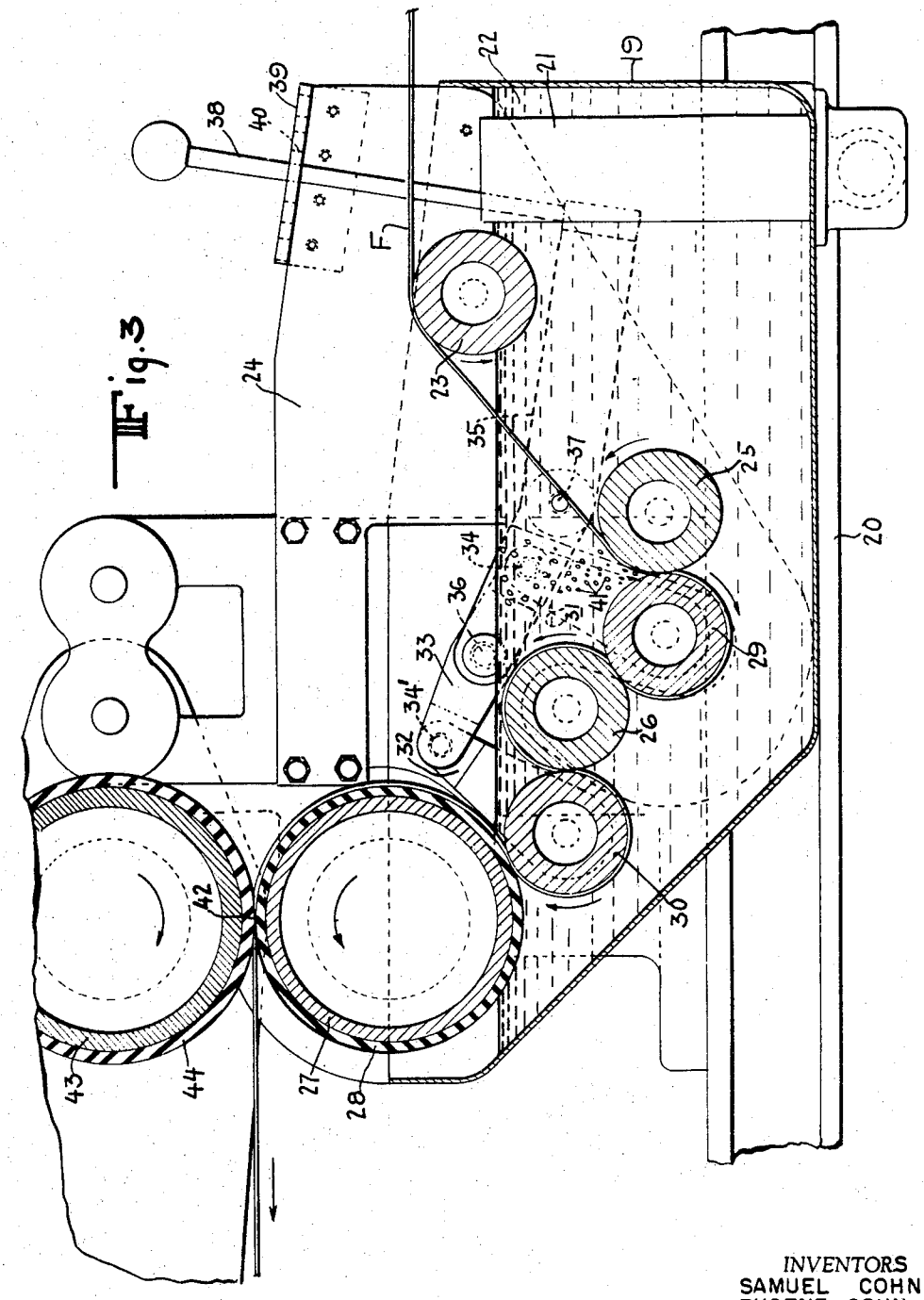
Fig. 3



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METHOD FOR DYEING TUBULAR KNIT MATERIAL

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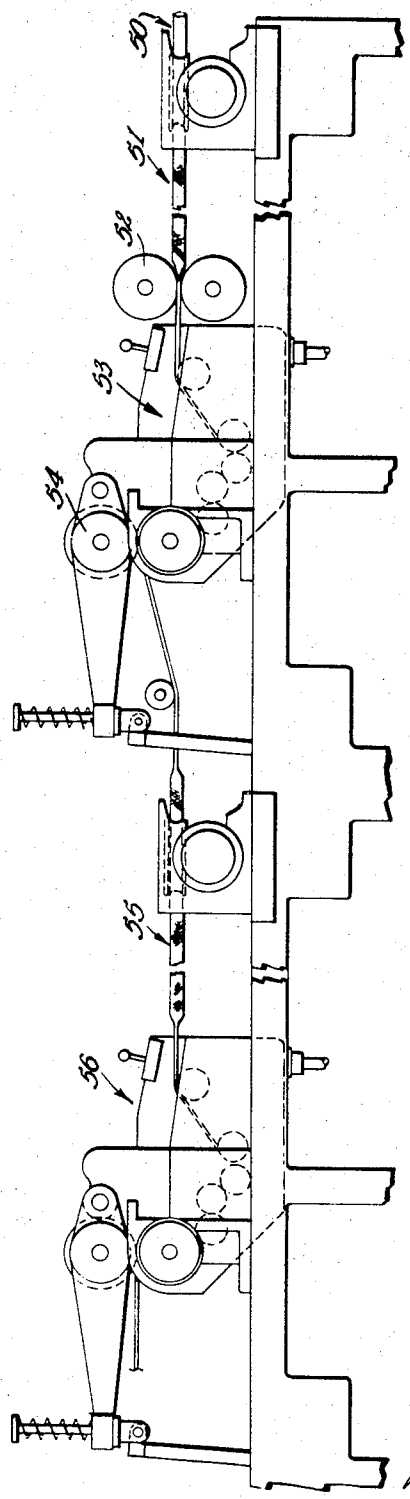

Fig. 4

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3,412,411
METHOD FOR DYEING TUBULAR KNIT MATERIAL

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Application Aug. 14, 1963, Ser. No. 302,094, now Patent No. 3,263,458, dated Aug. 2, 1966, which is a continuation of application Ser. No. 55,672, Sept. 13, 1960. Divided and this application June 27, 1966, Ser. No. 560,764

8 Claims. (Cl. 8—151)

ABSTRACT OF THE DISCLOSURE

A process for the continuous dyeing of tubular knitted fabrics is disclosed. The process includes alternately exposing opposite sides of the tubular knitted fabric to a dye bath while the fabric is in a flat condition and continuously submerged in the dye bath. A uniformly dyed tubular knitted fabric, free of edge marks, is thereby achieved.

This application is a division of our copending application Ser. No. 302,094, filed Aug. 14, 1963, now United States Patent No. 3,262,458, granted Aug. 2, 1966, which application is a continuation of application Ser. No. 55,672, filed Sept. 13, 1960, now abandoned.

The present invention relates to the treatment of tubular knitted fabrics and, more particularly, to a novel and improved method for continuously dyeing tubular knit material in a manner to provide a dyed tubular fabric free of edge marks.

The dyeing of fabrics is desirably carried out on a continuous basis, by directing a web of bleached or scoured material through a bath of dye liquor and uniformly impregnating the material with the dye. Such continuous dyeing has been carried out successfully with woven materials, for example, in which the material to be treated is in open-width form (i.e., in the form of a single-layered web). However, notwithstanding its many potential advantages, continuous dyeing has not been applied successfully, heretofore, to the treatment of tubular knit fabrics, although the industry has attempted for many years to develop commercially practicable methods to do so.

In large part, at least, tubular material has been incapable of being successfully continuously dyed, heretofore, by reason of an inability to obtain uniformity of dyeing, and hence of color, throughout the entire extent of the tubular material. Specifically, tubular material is normally treated in flattened, two-layered form, which gives rise to substantial problems in connection with uniform penetration of the dye, particularly at the edges of the material. Thus, continuously dyed tubular material has been characterized, heretofore, by "edge marks," or areas at the edges of the tube where the coloring is either lighter or darker than over the remaining area. Such edge marks render the material unsuitable for commercial use, as they result in unwanted continuous lines or streaks in a lengthwise direction along the edges of the fabric tube. And while these streaks are initially at the edge, which in itself is very undesirable, further processing of the tubular fabric causes the streaks to appear at any point in the finished fabric, because of fabric reorientation, which creates new edges, and this is wholly intolerable. Moreover, with tubular fabric, both sides or surfaces must be absolutely uniform as regards color shading since, as mentioned, the two principal sides of the fabric may and usually will be reoriented during further processing.

In accordance with the present invention, novel arrangements are provided for delivering, in a continuous, controlled process, a commercially acceptable dyed tubular knitted fabric, free of so-called edge marks, color variations on opposite sides, and other common defects. To this end, the invention provides an improved method of treating tubular knitted fabric, whereby the material is penetrated uniformily and thoroughly by the dye liquor on both principal layers of the fabric tube and at the doubled-over edges, whereby edge marks, color variations on opposite surfaces, and other defects, at the edges or folds of the material or elsewhere, are effectively eliminated.

Generally stated, the method of the invention involves the first important step of presenting the tubular knitted fabric in flat form and at a predetermined uniform width. The uniform-width fabric is then submerged in a bath of dye liquor and there subjected to a succession of squeezings under concentrated pressure. We have discovered that as soon as practicable after entering the dye bath, the tubular web should be subjected to a nipping pressure, which advantageously may be applied by a pair of pressure rolls, in order to close the tube and expel any air entrapped within the tube, which would tend to cause ballooning of the tube. Particularly if the fabric is dry, the initial air expulsion is most advantageously accomplished by nipping the fabric below the surface of the bath and while it is still traveling downwardly; this facilitates the release and upward escape of the expelled air bubbles. During the successive squeezings, the fabric is maintained continuously and wholly submerged in the dye bath, and the opposite sides of the fabric are alternately exposed to the dye liquor. At the same time, the generally elastic and dimensionally unstable fabric is maintained under constant dimensional control to provide uniform fiber and stitch conditions, which promotes uniform penetration and acceptance of the dye. The succession of submerged squeezings is such in number and character as to reliably assure complete and uniform dye penetration, even at the doubled-over edge portions of the fabric tube. The thus uniformly and thoroughly impregnated fabric is immediately thereafter, and while being maintained under complete dimensional control, passed through a resilient nip to reduce the dye liquor content to a predetermined uniform level. During this entire period the fabric must be maintained continuously submerged in the dye bath, because exposure to air could and usually would result in nonuniformities between surfaces.

As one of the more specific but significant aspects of the invention, the tubular knitted fabric is directed into a dye bath and passed through a series of concentrated pressure nips for successively squeezing and releasing the fabric a plurality of times while the fabric remains wholly submerged in the dye bath and under continuous dimensional control. Immediately thereafter the fabric is passed through a pressure nip, which controllably limits the amount of uniformly penetrated dye liquor to be retained in the fabric. Throughout the treating sequence, advantageously from the first to the final pressure nip, the normally elastic and easily distortable fabric is maintained continuously in control contact with dimensionally stable surfaces, so that the internal structure and geometry of the fabric is kept uniform, as is the ability of the fabric to receive and retain dye uniformly. Advantageously, during the successive, submerged squeezings of the fabric in submerged pressure nips, opposite sides of the tubular fabric are alternately exposed to the dye bath (one side always being in contact with a surface) to optimize the uniformity of dye penetration from either side.

After passing through the series of high pressure working nips, being continuously submerged, the fabric is brought up out of the dye bath, still in contact with the dimensionally stable surface, and subjected to a resilient

extracting pressure, so chosen and so regulated, that excess dye bath liquid is extracted from the fabric, uniformly across the fabric width and at the edge extremities. It is necessary and desirable that the fabric be exposed beneath the surface of the liquor bath at least briefly after being subjected to the final working pressure. This provides for a cascade of the dye liquid over and about the fabric as it is carried upward from the bath and into the extracting nip, which cascade maintains the fabric effectively immersed in the dye liquid until the final extraction step, at which time the dyeing process is complete (except for curing or fixing of the dye, if necessary). Maintenance of a rather precise liquid level in the dye bath has been established to be a very important aspect of the invention, because of its effect upon the final cascade of dye liquid about the fabric as it travels upward to the extracting nip.

The invention also provides for the two-stage treatment of tubular knitted fabric in which the fabric is impregnated in a first stage, with a uniform quantity of a first liquid and in a second stage, with a uniform quantity of a second liquid.

In the treatment of goods in two stages, as in the single-stage treatment, the fabric is caused to have uniform dimensions and conditions during the first stage of treatment to assure uniformity of penetration and absorption. To this end, the material is laterally distended or spread to a predetermined width and uniform condition, at some stage prior to entry into the first treating bath, and this condition is carefully maintained during passage of the material through the treating bath by reason of constant contact of the material with surface portions of the non-resilient friction-driven rollers. The treated material emerging from the first stage may again be set to predetermined width or, where advantageous or expedient, the material may be directed immediately into the second stage bath while maintaining uniform conditions of width and tension, etc. The teachings of this aspect of the invention are particularly applicable to advantage in connection with the treatment of materials in successive stages, where the first stage, or perhaps an intermediate stage, may be a water treatment or a treatment with active solution. Thus, in conjunction with a dyeing treatment, it may be desirable to precondition the material uniformly with a penetrant or other pretreatment solution. Further, it may be desirable and advantageous to carry out the dyeing operation in two or more distinct stages, either with or without a step involving water or other preconditioning solution.

In connection with the treatment of dry materials, the invention provides for preconditioning of the material when necessary or desirable by steaming the material while distending it to uniform width, prior to entry of the material into the dye bath or into a preconditioning water bath. By thus steaming the material, while distending it to predetermined, uniform width, certain materials may be rendered more uniform in structure and therefore capable of uniformly accepting the dye or preconditioning bath. The steamed material may also be somewhat more uniformly conditioned from the standpoint of heat and moisture content, which can aid importantly in bringing about uniformity of dye penetration. The steamed material could also be spread to an extra wide width to enable the rate of dye penetration to be increased.

For a better understanding of the invention, and for a further discussion of the above and other novel and advantageous features thereof, reference should be made to the following detailed description and to the accompanying drawings, in which:

FIG. 1 is an elevational view of an apparatus for use in carrying out the method of the invention;

FIG. 2 is a top plan view of the apparatus of FIG. 1;

FIG. 3 is an enlarged, fragmentary, cross-sectional view taken generally on line 3—3 of FIG. 2; and

FIG. 4 is a simplified schematic representation of a processing line, incorporating apparatus as illustrated in FIG. 3, for treating goods in two stages.

Referring now to the drawings, the reference numeral **10** designates, generally, a representative form of combination spreader and propelling device, which may be of the type described in the S. Cohn et al. United States Patent No. 2,385,402, for example. The spreader **10** is positioned to receive tubular material from a prior processing station, as part of a continuous process, and uniformly conditions the material and distends it laterally to a predetermined width. The spreader also advances the material toward a dyeing station, designated by the reference numeral **11**. The material received by the spreader **10** may be bleached or scoured, and may be in either wet or dry form. If the material is in dry form, it may sometimes be advantageous to provide steamers **12** in association with the spreader **10**, so that the material may be steamed in connection with the operation of distending it to a predetermined width. The steaming not only sets the fabric in its distended form and enables the material to be rendered structurally uniform, but also heats it uniformly and imparts uniform moisture thereto, all of which can importantly affect the uniformity of dyeing. While it is necessary, of course, for the fabric to be presented to the dye bath in flat form and in a substantially uniform, geometric condition, it is sometimes possible to so precondition the fabric in a prior, separate processing operation.

If the fabric is taken directly from a bleaching operation, for example, and is in wet form, a pair of squeegee rolls **13** may be provided to remove as much of the residual treating liquids as possible from the material after it is passed over the spreader **10**. Where the material is received in wet form, the steamers **12** usually may be omitted, but they may also be utilized to advantage on occasion for elevating the temperature of the fabric. By spreading the wet material to a predetermined, uniform width, the various tensions in the material are rendered substantially uniform, enabling dye penetration to be effected with desired uniformity, as will be described.

The illustrated spreader device **10** consists of a pair of belts **14, 15** supported within the fabric tube by a frame **16** and driven by a pair of edge rolls **17, 18**. The frame **16** may be adjusted to a predetermined width, to stretch the fabric widthwise to a predetermined extent, and the fabric is propelled forward over the spreader by means of the belts **14, 15** driven by the edge rolls **17, 18**. In the illustrated arrangement, the speed of the fabric on opposite sides of the edge roller **17, 18** is the same. The illustrated spreader equipment is particularly useful where some degree of lateral distension of the fabric is necessary or desirable. If the presented fabric already is of uniform width, from a separate, prior operation, the spreader may be simplified or perhaps omitted.

In the treatment of certain dry fabrics, the fabric may be subjected to steaming, by means of the steamers **12**, while on the spreader **10**. This "lubricates" the fibers of the material and enables them to reorient as necessary.

In FIGS. 1–3, the fabric travels from the spreader **10** to a dye bath maintained in a reservoir **19**. If wet fabric is treated, the fabric is passed between the squeegee rollers **13**, during its travel between the spreader and the dye bath, so that excess water or other liquid is removed from the material and a desired liquid content in the material is achieved. The fabric thus conditioned is immersed in the dye bath and subjected therein to an action resulting in the thorough and uniform penetration of the dye, in a manner to be described.

Referring now to FIG. 3, the reservoir **19** of the dyeing apparatus is supported on a frame **20** and provided with means, such as an overflow pipe **21** which, in combination with appropriate dye inflow means (not shown), maintains the dye bath **22** at a predetermined level. Uniformity of the dye level is considered to be a factor of

prime significance in the obtaining of uniform dyeing results.

The fabric F travels over the dye bath **22**, at the entry or righthand side thereof, and passes over a guide roller **23** mounted in a frame **24** at a level such that at least part of the roller is exposed above the level of the bath.

Mounted in the frame **24**, below the level of the bath, are non-resilient pressure rollers **25**, **26**, which advantageously are arranged to rotate freely in the frame. Spaced above and to the left of the pressure roller **26**, so as to be only partly immersed in the dye bath **22**, is an extracting roller **27** which advantageously is of relatively large diameter and has a surface covering **28** of resilient material, as will be described. The roller **27** is mounted in the frame **24** and is connected to suitable drive means D (FIG. 2).

As illustrated in FIG. 3, the rollers **25**, **26** and **27** are arranged somewhat in a line, and each is spaced a predetermined distance from the adjacent roller or rollers. Mounted below the rollers **25–27** and positioned generally in the spaces between those rollers are non-resilient pressure rollers **29**, **30**, which advantageously are the same diameter as the pressure rollers **25**, **26**, which diameter is somewhat larger than the spaces between the rollers **25**, **26** and **26**, **27**.

Advantageously, the pressure rollers **29**, **30** are suspended at their opposite ends by arms **31**, **32**, which are pivotally connected to a yoke **33** at points **34**, **34'**. The yoke **33** is, in turn, connected to control means, such as a lever **35**, by a pivot **36** located substantially centrally between the pivots **34**, **34'**. The lever **35** is pivoted at **37** on the main frame **24** and has mounted at one end a hand lever **38**, for example, by means of which the lever **35** may be manipulated. The hand lever **38** cooperates with a bracket **39** having therein a plurality of notches **40** which receive the hand lever **38** and lock it in any of a plurality of positions.

By appropriate manipulation of the hand lever **38**, the rollers **29**, **30** may be moved toward and away from the pressure rollers **25–27**. Thus, to thread the fabric F through the machine, the hand lever **38** is moved forward to lower the pressure rollers **29**, **30**. The fabric F is then threaded first between the rollers **25**, **29**, next between rollers **29**, **26**, then between rollers **26**, **30** and, finally, between rollers **30**, **27**. The hand lever **38** is then drawn rearwardly and engaged in one of the notches **40**. The rollers **29**, **30** are thereby drawn tightly against the rollers **25–27**, forming therewith a plurality of submerged roller nips through which the fabric passes. By suspending the yoke **33** centrally between the pivot points **34**, **34'**, it is assured that the rollers **29**, **30** will engage the rollers **25–27** with uniform pressure, so that each of the several roller nips formed by the roller pairs **25** and **29**, **29** and **26**, and **26** and **30** is substantially the same as regards nip pressure. Advantageously, the hand lever **38** is formed of steel rod, for example, providing for a certain measure of springiness or yield. Accordingly, once the rollers **29**, **30** are brought into engagement with the rollers **25–27**, the nip pressure may be regulated by deflecting the hand lever **38** and locking it in a deflected position by means of the notched bracket **39**.

In accordance with one of the specific aspects of the invention, the first pressure nip, through which the fabric F is passed substantially immediately after it enters the dye bath **22**, is so oriented that the fabric passes through the nip while moving in a generally downward direction. In the illustrated apparatus, the first submerged pressure nip is formed by the non-resilient rollers **25**, **29** and the fabric F passes directly to this nip from the guide roller **23**. The arrangement of the first nip in this manner is advantageous in that the fabric is squeezed flat under forcible pressure to displace any air which may be trapped within the tube. Generally, a relatively large volume of air is expelled from the material at the first nip and it is important to release the air from above the nip to facilitate escape of the air, as indicated by the series of bubbles at **41**. Otherwise, the air is apt to become trapped within the fabric tube.

As the fabric passes through the series of submerged nips, including the first nip, the fabric is compressed forcibly and with highly concentrated pressure by the non-resilient rollers **25**, **26**, **29**, **30**, so that air and liquid is thoroughly forced out of the fibers in an effective and uniform manner. As the fabric emerges from each pressure nip, the concentrated nip pressure is suddenly released from the fabric and the dye liquor is drawn into the fibers to replace the air and liquid expelled therefrom during passage through the nip. This results in a sponge-like action in the fabric, whereby air and liquid are repeatedly and thoroughly expelled under concentrated nip pressure from the fabric and liquor is then drawn back into the fibers to penetrate all portions of the fabric in a highly effective and uniform manner.

In accordance with one of the significant aspects of the invention, the fabric traveling through the series of submerged, concentrated pressure nips formed by the non-resilient rollers **25**, **26**, **29**, **30** is at all times maintained in edge-to-edge control contact with at least one of the rollers. Accordingly, the tubular knit fabric, which is inherently unstable in character and easily distorted, is effectively retained in its original dimensions, preventing gathering and wrinkling of the fabric and assuring maintenance of the uniform tension conditions in the yarns of the fabric. In this respect, it is a feature of the invention that the tubular knit fabric is maintained constantly under geometric and dimensional control from the point of its entry into the first concentrated pressure nip, formed by rollers **25**, **29**, to the point of emergence of the dyed fabric from the extraction nip, constituting the last instance of squeezing or otherwise working the fabric during the dyeing process. Advantageously, this is accomplished by maintaining the fabric in edge-to-edge control contact with roller surfaces throughout. By this means, the unstable, easily distortable fabric is maintained reliably and controllably uniform throughout the processing of the fabric in the presence of the liquor so that conditions are proper for uniform acceptance of the dye by the fabric.

In addition, and as another important facet of the invention, the tubular knitted fabric traveling through the series of concentrated pressure working nips has its opposite sides alternately exposed to the dye liquid. In this respect, the opposite surfaces of tubular knitted fabric in process do not represent "front" and "back," as is the case with woven fabrics and other materials handled in open width form, but both the "top" and "bottom" surfaces are "outside" surfaces of the finished fabric. As a result, unless both surfaces are dyed to an identical shade, the finished product is inferior, if not useless. Thus, in the system of the invention, the concentrated pressure working nips, and the non-resilient rollers forming them, are wholly submerged in the dye liquid so that, as the fabric passes through the nips in sequence, with one surface always in contact with a roller, the opposite sides of the fabric are alternately exposed to the dye bath.

In the illustrated form of the invention, the covered roller **27** is driven by the drive means D, and the rollers **25**, **26** and **29**, **30** are driven at corresponding peripheral speeds by reason of the frictional contact between the series of rollers and the fabric passing between the roller nip. In this manner, lengthwise tensions on the material, which might otherwise change in passing the material through one or more roller nips, are maintained at a highly uniform level.

In accordance with the invention, the successive high pressure squeezings of the uniformly conditioned material, as it passes through the successive, submerged working nips in the dye bath, are such, in number and effectiveness, as to penetrate the fabric uniformly with an

excess of the dye liquor. Moreover, and particularly as a result of working in non-resilient submerged nips, the extreme edge portions of the fabric, where the material curves around from one flat to another, are thoroughly penetrated by an excess of dye, and this constitutes an important accomplishment of the invention as it enables the finished product to be free of "edge marks" characteristic of material attempted to be dyed continuously by known procedures and with known equipment.

After the fabric F has passed through the series of submerged working nips formed by the rollers **25–27, 29, 30** the fabric travels upward, around the surface of the partly submerged roller **27**, and through an extracting nip **42** formed by the roller **27** and a similar roller **43** located directly above, providing a cascade of dye liquid about the fabric portions traveling between the final submerged working nip and the non-submerged extracting nip **42**. The rollers **27, 43** are provided with coverings **28, 44** of resilient material, advantageously rubber, and, as the fabric passes through the nip **42**, pressure is applied by the rollers **27, 43**, to extract excess dye uniformly from the fabric, leaving a uniform, predetermined amount of the dye in the fibers.

In accordance with one aspect of the invention, the operation of extracting the excess dye from the fabric is carried out in a manner calculated to assure uniformity of dye coloring throughout the entire area of the fabric, including its edges. At the extreme edges of the fabric, the material curves around, and narrow strips at the extreme edges of the material may not be acted upon by the extracting rollers in the same manner as the flat surfaces of the fabric. However, we have found that, by imparting to the surfaces of the rollers **27, 43** the proper degree of resilience, so that the rollers are neither too soft nor too hard, the extracting step may be carried out with substantial uniformity throughout all areas of the material, avoiding edge marks and other defects. Of course, thorough dye penetration in excess quantities, reliably achieved as in accordance with the invention, is necessary to enable the extracting operation to be carried out in a manner such that the finished product is free of edge marks, etc.

One of the advantageous aspects of utilizing extracting rollers having relatively resilient surfaces is that, due to deformation of the surface material, the nip **42** is relatively broad, in a direction lengthwise of the fabric. This assures thorough extraction of the excess dye, as well as a sustained uniformity of action on the material. In addition, the characteristics of the surface material of the extracting rollers have a substantial effect on the treatment of the material at the extreme edges. Thus, if the extracting rollers have excessively hard surfaces, the material will be subjected to increased pressure at the extreme edges while, if the surface material is too soft, it may deform and close about the edges of the material to an undesirable extent. In either case, undesirable edge marks on the material will result.

The pressure at the extracting nip advantageously is controlled in a relatively precise manner by mounting the upper roll **43** on a lever **45** pivoted on the frame **24** by means of a pin **46**. The free end of the lever **45** may have attached thereto a suitable spring device **47**, for example, capable of relatively precise adjustment, so that the extracting roll pressure may be adjusted in an accurate manner. A typical adjusting arrangement suitable for this purpose is illustrated in the S. Cohn et al. United States Patent No. 2,729,003, for example.

After the fabric F leaves the dye bath and passes through the extracting nip **42**, subsequent treatments usually are applied, depending on the nature of the dyeing or processing. The material may then be dried and cured or otherwise treated, as may be desired.

The method and apparatus above described are particularly useful in the treatment of dry fabrics and may be used successfully in the treatment of wet fabrics. However, the invention additionally contemplates the provision of arrangements for uniformly and controllably wet preconditioning the fabric, prior to dyeing, enabling the dyeing operation itself to be carried out with desired, superior uniformity.

In this respect, it has been found that, in continuous dyeing of wet fabric, where the material has a relatively short period of exposure to the dye liquor, uniformity of liquid content of the fabric is important to the achievement of uniformity of dyeing. Thus, whereas the system of FIG. 1 may be adequate for the treatment of wet material whose starting or initial water content is fairly uniformly excessive, such relatively ideal conditions may not be present always and the treatment may have to be carried out with material which is wet, but not containing either a uniform or an excess quantity of liquid, or with dry material which it is desired to wet prior to immersion in the dye bath.

Referring now to FIG. 4, there is shown a processing line especially arranged, in accordance with the invention, for the two-stage treatment of tubular knitted fabric. The starting material **50** may be in wet form, as received from prior processing operations, such as bleaching and subsequent, related treatments, and the material in this form is, in accordance with the invention, passed over a spreader **51**, which may correspond in construction and operation to the spreader **10** of FIG. 1. While passing over the spreader **51**, the fabric **50** is distended to a predetermined uniform width, and desired, uniform conditions of tension are imparted to the material.

Advantageously, as the fabric leaves the exit side of the spreader **51**, it is passed between squeegee rollers **52**, which remove a substantial amount of excess liquid from the material. This usually is desirable, since the liquid contained in the fabric may contain chemicals from prior treatments, whose presence in the material in substantial quantities may undesirably affect the further treatment thereof.

After the material **51** has been spread, and has passed through the squeegee rollers **52**, if used, it is directed into an impregnation unit **53** containing water or other solution. The unit **53** advantageously is of the same construction as the dyer unit **11** of FIGS. 1–3. The fabric passes downward into the solution and successively through a series of wholly submerged high pressure working nips formed by contacting, friction-driven, non-resilient rollers, all as clearly indicated in FIG. 3. At each working nip, solution and air are forcibly expelled from the fabric and, as the material emerges from a nip and is released by the roller, solution is drawn back into the material, thoroughly penetrating the fibers of the material. By reason of the successive squeezing and releasing actions under concentrated pressures while the fabric remains submerged in the solution, a uniform excess of the solution penetrates the entire body of a material.

As the fabric traveling through the solution is subjected to a sponge-like action by successive squeezing and releasing operations, it is maintained in continuous contact with rollers so that the fabric does not tend to narrow down from its preset width. Moreover, as before described, the various rollers forming the submerged nips are driven by frictional contact with each other, through the interposed material, so that tensions in the material are not varied during the course of travel through the solution.

Material emerging from the pretreating solution is uniformly impregnated with an excess quantity of solution, and this material is passed through extractor rollers **54**, corresponding to the rollers **27, 43** of FIG. 3 and forming part of the impregnation unit **53**. The action of the rollers **54** is such as extract from the material the excess quantities of solution, leaving a predetermined, uniform quantity precisely suited for subsequent dyeing of the material.

In the system illustrated in FIG. 4, the solution-impregnated material leaving the unit **53** is passed over a second

spreader **55**, which may be of the type before described. This spreader re-establishes precise geometric control over the fabric. And, if desired, the material may be set at some other width calculated to provide a desired level of uniform tension for dyeing.

In certain cases, where adequate geometric control of the fabric is otherwise maintained, the second spreader may be eliminated altogether, and the solution-impregnated material taken directly into the dye bath from the extractor rollers **54**.

The impregnated and otherwise preconditioned material, after spreading if the unit **55** is employed, is directed into a second apparatus **56**, which, for the purpose of this description, may be similar in all material respects to the unit shown in FIG. 3. Processing of the preconditioned, wet material in the unit **56** takes place substantially in the manner before described in connection with the system of FIGS. 1–3. The emerging, dyed material is highly uniform in nature, free of edge marks and otherwise of high quality character.

In a system, such as shown in FIG. 4, the material may be subject to two or more distinct treatment steps. In many instances, at least one of such steps will be a water pretreatment step, but it may be advantageous to carry out a plurality of separate treatment steps with or without a water pretreatment step. Certain dyes, for example, are typically applied in a two-stage process, and the system of the invention may be utilized to carry out such a two-stage process as a part of a continuous operating line.

The new method represents a substantial advance in the art, by providing a method of dyeing tubular knitted fabric continuously to produce commercially acceptable dyed tubular knitted fabric free of edge marks. Thus, bleached or scoured fabric, taken in either a wet or dry state, may be passed continuously in the form of a flat web of doubled material through the dyeing apparatus and directly to the subsequent processing stations, such as a salt bath and rinse or steam chamber, for example, in accordance with conventional practice. Heretofore, it has been deemed impossible to dye tubular knitted material on a continuous basis in a competitive manner productive of commercially acceptable finished fabric free of edge marks, notwithstanding that continuous dyeing has been done successfully for many years with woven fabrics. With the method of the invention, however, the various difficulties have been overcome in a manner assuring thorough and uniform penetration of the fibers by the dye liquor, followed by uniform extraction of excess dye.

One of the particularly important aspects of the invention resides in the working of the tubular knitted fabric by applying substantial concentrated working pressures to the fabric as it passes through a treating solution. The arrangement is such that the tubular knitted fabric is subjected to a succession of high pressure squeezing operations, to displace liquid and air, followed by a quick release of the concentrated squeezing pressure, to cause the fabric to draw the dye liquid thoroughly into all of its fibers. Moreover, this procedure enables the fabric to absorb a uniform excess of the dye liquid, a condition which has been heretofore unattainable in a practical continuous operation with tubular knitted fabrics.

In conjunction with the subjection of the fabric to a succession of high working pressures, at least one surface of the tubular knitted fabric is at all times maintained under edge-to-edge control. Thus, the geometric conditions of the inherently elastic and unstable tubular knitted fabric are, to the greatest practicable extent, maintained uniform and under effective control. This is particularly important to enable the tubular knitted fabric to accept the dye liquid in a uniform manner and is a factor which, prior to our invention, has not been adequately recognized and appreciated. Specifically, it is a feature of this invention that the tubular knitted fabric is maintained under dimensional control from the point of its initial entry into the first submerged working nip to the point of its emergence from the extracting nip. Accordingly, all of the working operations performed on the tubular knitted fabric in the presence of the dye liquid are performed while the fabric is maintained geometrically stabilized.

As a further specific aspect of the invention, the tubular knitted fabric, while passing through the treatment bath and being subjected to a series of working pressures while having at least one surface maintained in edge-to-edge control, has its opposite sides alternately exposed to the dye liquid. In this respect, it was recognized that the ability of the fabric to absorb the dye liquid in the region of the surface thereof in contact with a dimensionally stable roller surface may be limited relative to the opposite surface. Accordingly, provisions are made in accordance with the method of the invention to cause first one side and then the other of the fabric to be in control contact with a roller surface, as the fabric progresses through the bath and is subjected to a series of working pressures while submerged in the bath. The alternately non-contacting surfaces of the fabric thus are exposed successively to the dye liquid so that, in the course of the submerged working of the fabric, both sides of the fabric are exposed to the dye liquid.

The various aspects of the present invention particularly recognize and accommodate the fact that all of the exposed surfaces of a tubular knitted fabric constitute "outside" surfaces of the finished fabric, as distinguished from the typical woven fabric, for example, in which one surface is the "outside" and one surface is the "inside." Thus, in the dyeing of tubular knitted fabric, it is absolutely essential that both the "top" and the "bottom," and also the edge extremities, assume exactly identical dye shades. Any shade differential between sides, or any marks or lines along the edge extremities, will render the fabric practically worthless, since the consumer obviously desires color uniformity in the final garment. This is particularly true in view of the fact that the "edges" of the fabric during the dyeing operation may not be the "edges" of the fabric at a later stage in processing, so that a shade differential line or an edge mark may extend along a principal flat surface of the finished fabric tube.

A significant achievement of the present invention is the ability to impart to the tubular knitted fabric, during its continuous passage through a dye bath, a uniform excess of the dye liquid in all of the fibers and yarns of the fabric, including the edge extremities and including the "top" surface to the same extent as the "bottom" surface. This greatly reduces the criticality of the subsequent extracting operation, by which the excess dye is removed from the fabric to achieve a high quality, uniform product. A further significant achievement resides in the ability to achieve thorough, uniform penetration in a relatively short course of fabric travel, so that the set-to-width and geometrically stabilized fabric tube may be maintained under geometric control throughout. The short course of fabric travel, itself, enables the process to be carried out with small quantities of dye liquor in the system and thereby facilitates the control of a uniform temperature in the dye bath, an important factor in the quality of continuously dyed goods.

The most important ultimate advantage of the new method results from the fact that the dye station may be incorporated in a continuous tubular knitted fabric processing line, so that the fabric may be subjected to an entire series of processing operations on a high-speed, continuous basis. Heretofore, dyeing of tubular fabric has been carried out only on a batch basis, usually by placing lengths or strings of the fabric in a dye vat. This has involved an interruption of the continuous processing sequence and has, in addition, involved additional operating steps in preparing the fabric for the dye vat and sub-

sequently conditioning it for further continuous processing.

It should be understood that the specific methods herein illustrated and described are intended to be representative only, as certain changes may be made therein without departing from the clear teachings of the disclosure. Accordingly, reference should be made to the following appended claims in determining the full scope of the invention.

What is claimed is:

1. The method of continuously dyeing tubular knitted fabric to provide dyed tubular knitted fabric having a uniform appearance throughout its circumference and being free of edge marks, which comprise

(a) presenting the tubular fabric in flat tubular form and at a uniform, predetermined width,

(b) guiding the fabric in flat, tubular form into a bath of dye liquid while maintaining the fabric in a substantially uniform geometric condition,

(c) applying a series of concentrated squeezing pressures to the fabric, while maintaining the fabric continuously wholly submerged in said dye bath, to thoroughly impregnate all portions of the fabric tube, including the doubled-over edge portions, with dye liquid,

(d) alternately exposing the opposite layers of said tubular knitted fabric to said dye bath during the application of said series of concentrated squeezing pressures,

(e) during the application of said concentrating squeezing pressures, maintaining alternately unexposed layers of said tubular knitted fabric continuously in edge-to-edge dimension stabilizing control contact with dimensionally stable, synchronously moving surfaces, and

(f) while maintaining the fabric tube in a flat condition, removing said fabric from said dye bath and applying resilient squeezing pressure to the fabric to extract excess dye liquid therefrom.

2. The method of claim 1, in which

(a) the tubular knitted fabric is guided in a generally downward direction into the dye bath and directly to the point of applying the first of said series of concentrated squeezing pressures,

(b) The fabric tube being squeezed first while moving generally downwardly to facilitate the upward escape of air expelled from the squeezed-closed tube.

3. The method of continuously dyeing tubular knitted fabric to provide dyed tubular knitted fabric having a uniform appearance throughout its circumference and being free of edge marks, which comprises

(a) presenting the fabric in a flat [two-layer] tubular form and at a uniform, predetermined width,

(b) guiding the fabric substantially directly into a bath of dye liquid,

(c) alternately engaging and continuously maintaining the geometric stability of the two layers of said fabric while causing opposing layers alternately to be directly exposed to the dye bath,

(d) applying a series of concentrated, non-resilient squeezing pressures to the fabric while maintaining the fabric wholly and continuously submerged in said dye bath and while said fabric is maintained geometrically stabilized by continued engagement of at least one of its layers,

(e) removing the fabric from said dye bath and applying resilient squeezing pressure to the fabric to extract excess dye liquid therefrom, and

(f) maintaining the fabric in a geometrically stabilized condition by contact with a moving external surface, while said fabric is being removed from said dye bath and while excess dye liquid is being extracted from the fabric.

4. The method of claim 3, in which

(a) said fabric is maintained continuously in full contact with a moving dimensionally stable surface from the point of applying the first of said series of concentrated, non-resilient squeezing pressures to the point of completing the application of said resilient squeezing pressure.

5. The method of claim 3, in which

(a) said fabric, upon removal from said bath, is directed upwardly to a station at which said excess dye liquid is extracted therefrom,

(b) whereby at least a portion of the excess dye liquid extracted at said station is cascaded over fabric approaching said station, to minimize exposure of said fabric to air prior to completion of the extracting step.

6. The method of claim 5, in which

(a) said fabric is exposed to said cascading dye liquid during the entire interval in which it travels from said bath to said station.

7. The method of continuously dyeing tubular knitted fabric to provide dyed tubular knitted fabric having a uniform appearance throughout its circumference and being free of edge marks, which comprises

(a) supplying tubular knitted fabric in flat, tubular form at a uniform, predetermined width,

(b) guiding the fabric into a bath of dye liquid,

(c) applying a series of concentrated squeezing pressures to the fabric, while maintaining the fabric continuously and wholly submerged in the dye bath, to thoroughly impregnate all portions of the fabric tube, including the doubled-over edge portions, with dye liquid,

(d) alternately exposing the opposite layers of said tubular knitted fabric to said dye bath during the application of said series of concentrated squeezing pressures,

(e) during the application of said concentrated squeezing pressures, maintaining alternately unexposed layers of the tubular knitted fabric in edge-to-edge dimension stabilizing control contact with dimensionally stable, synchronously moving surfaces, whereby the fabric is continuously stabilized,

(f) while maintaining the fabric tube in a flat condition, removing the fabric from the dye bath and applying resilient squeezing pressure to the fabric to extract excess dye liquid therefrom, and

(g) causing the extracted dye liquid to cascade over the fabric as the fabric travels from said dye bath to the point at which said resilient squeezing pressure is applied.

8. The method of claim 7, further characterized by

(a) said tubular knitted fabric being laterally distended to said uniform predetermined width directly in advance of said dye bath and as an integrated part of said method.

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