(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number : **0 480 776 A1**

(12) **EUROPEAN PATENT APPLICATION**

(21) Application number : **91309427.2**

(22) Date of filing : **14.10.91**

(51) Int. Cl.^{5} : **D06C 15/14,** D06C 19/00, D02J 3/02

(30) Priority : **12.10.90 US 596271**
08.08.91 US 742897

(43) Date of publication of application :
15.04.92 Bulletin 92/16

(84) Designated Contracting States :
AT BE CH DE DK ES FR GB GR IT LI LU NL SE

(71) Applicant : **MILLIKEN RESEARCH CORPORATION**
920 Milliken Road
Spartanburg, South Carolina 29303 (US)

(72) Inventor : **Dischler, Louis**
1764 Hillcrest Boulevard
Spartanburg SC 29302, Spartanburg (US)

(74) Representative : **Pacitti, Pierpaolo A.M.E. et al**
Murgitroyd and Company Mitchell House 333 Bath Street
Glasgow G2 4ER Scotland (GB)

(54) **Method and apparatus for modifying fibers and fabric by fatiguing.**

(57) A method and apparatus is provided for modifying fiber or fabric by fatiguing that creates at least one of the following characteristics including : axially aligned cracks, physical change created by the bending and compression of the fiber along the fiber's longitudinal axis taking the form of kink bands, enlarged segregated fibular tangles or enlarged nodes. Fatiguing is defined as repeated stress on fiber by high velocity impact that bends the fiber and compresses it in a direction parallel to the fiber's longitudinal axis. Fatiguing results in softer hand and/or improved dyeability in some fabrics, including but not limited to liquid crystal fabrics and cellulosic vegetable fabrics. The application of one or more gas jets directed away from the interior curved surface of a cylinder, generating a vortex which rapidly and repeatedly cycles the substrate at low tension past the gas jets. The rapid vibrations generated in the substrate by the jets serve to break apart fiber to fiber bonds caused by finish and loosen up the structure of the yarns and that of the substrate. This creates a desired aged appearance as well as a very soft texture.

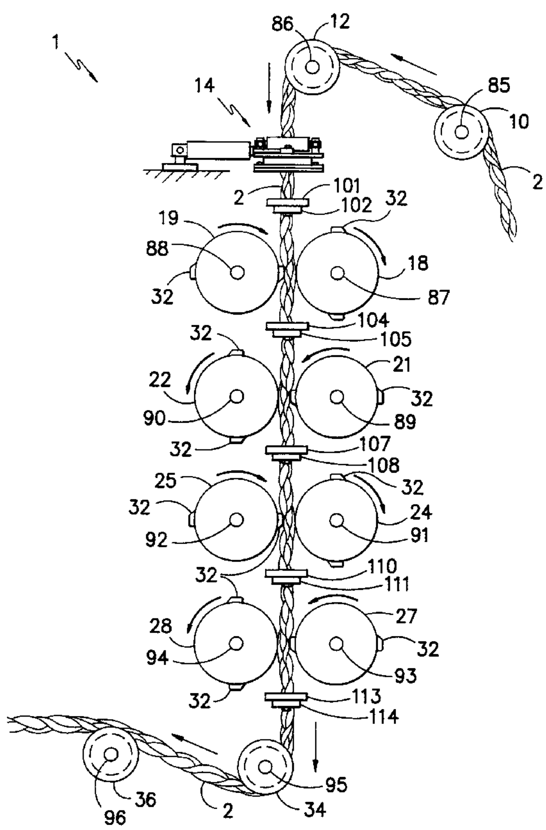


FIG. -1-

EP 0 480 776 A1

Background of the Invention

This invention relates to improving the hand and/or dyeability of yarns and fabrics.

An example of a type of yarn or fabric that can pose a severe problem with regard to both hand and dyeability are those constructed out of liquid crystal fibers. This would include both lyotropic and thermotropic liquid crystal fibers. A mere illustration of a type of thermotropic liquid crystal fiber is a fully aromatic polyester and a mere illustration of a lyotropic liquid crystal fiber would be an aromatic polyamide (polyaramid).

Fully aromatic polyester fibers have been found to be well-suited for cut resistant apparel as well as electrical insulation, ropes and cable, and so forth. These fibers have a high tensile strength, low elongation coupled with no measurable creep up to fifty percent of the breaking load, excellent chemical resistance and good physical property retention over a broad range of temperatures. An example of a fully aromatic polyester fiber is VECTRAN® manufactured by Hoechst Celanese Corporation and described in U.S. Patent No. 4,479,999 which is incorporated herein by reference.

Aromatic polyamide (polyaramid) fibers have also been found to be well-suited for application in areas for personal protection such as in ballistic vests and in cut resistant gloves. In areas where high strength is of primary importance, as in ballistic protection, fabrics of high modulus aramid fibers such as poly(para-phenylene terephthalamide) are used. Such high modulus fibers are hereinafter known as HM-aramid fibers. An example of a HM-aramid fiber is KEVLAR® manufactured by E. I. du Pont Nemours and Co. and described in U.S. Patent no. 4,198,494, which is incorporated herein by reference.

Therefore, it would be highly desirable to modify fibers such as the HM-aramid fibers, fully aromatic polyester fibers, among others, to increase dyeability with minimal degradation to physical properties as well as enhancing the hand.

It also would be desirable to enhance the hand of fabrics that are naturally dyeable to a relatively high degree, but when untreated, form very stiff and uncomfortable garments. Examples include cellulosic/vegetable fibers such as bast fibers, among others.

There are numerous methods of treatment to alter fabric and/or fiber. One method of treating textile fabric is by subjecting successive adjacent sections of fabric to intermittent mechanical impact with an abrasive means along the width of the fabric. Substantial sustained contact between the fabric and abrasive means is avoided with the mechanical impact being at a force and frequency sufficient to cause a substantially uniform modification of the surface characteristics of the fabric. In this process, an abrasive media is used to chisel away at outer fibers to bring up short hairs. This is disclosed in commonly assigned U.S. Patent No. 4,512,065 issued April 23, 1955, commonly assigned U.S, Patent No. 4,316,928 issued February 23, 1982, and commonly assigned U.S. Patent No. 4,478,844 issued September 4, 1984. There is no significant compression along the longitudinal axis of the fiber present to induce fatiguing. Furthermore the tensile strength of the fabric is significantly reduced due to resulting fiber destruction.

A second method of treating textile fabric is to subject the face and backside of fabric to successive impacting by a plurality of flaps to break the fiber or filament bond thereof and increase the yarn to yarn mobility therein. Commonly assigned U.S. Patent No. 4,769,879, issued September 13, 1988, discloses simultaneous impact of the flaps on both the front and the back of the fabric simultaneously and commonly assigned U.S. Patent No. 4,631,788, issued December 30, 1986, discloses an embodiment where the flaps do not contact the fabric therebetween to cause a streak thereon. Both patents disclose a method for mechanically conditioning textile materials while not providing repeated stress on fiber by high velocity impact that bends the fiber and compresses it in a direction parallel to the fiber's longitudinal axis.

Another method of treating textile fabric is that termed "fulling" or "bulking". This is a general or routine finishing process that utilizes the action of water moisture, friction and pressure with the fabrics being alternately compressed and extended. The action causes the fibers to swell and thicken thereby shrinking the yarn and closing the weave, which produces a soft fabric with full hand and body. In this case, the weave is compressed and not the fiber. This reduces the density of the fabric partially achieved by increasing the corrugation of the warp yarn and thereby loosening up the weave.

A fourth method of treating textile fabric is by the use of rubber belts to create microcorrugations in the fabric. In this process fabric contacts a thick rubber belt that is partially wrapped around a cylinder. At this point the outside of the belt that is in contact with the fabric is stretched while the inside of the belt that is in contact with the cylinder is compressed. The fabric and belt pass through a nip whereupon the belt wraps around a second cylinder and the curvature is reversed. This effectively compresses the fabric lengthwise since the fabric is trapped between the belt and the second cylinder. The warp yarns ar placed in compression, however, the fibers bend and are subjected to very little compressive force. The softening achieved by this process is by physically rearranging fibers and not by changing the physical characteristics of the fibers themselves. However, there is no significant impact or fiber compression.

A fifth method of treating textile fabric is that of jet dyeing and jet rope washing. Jet dyeing is when fabric tied in rope form is placed in a tube-like container and dyestuff is forced through pressure jets. The dye is continuously recirculated as the cloth moves or floats in a tension-free condition along the tube container at rapid speed. The movement of the fabric is controlled by the propulsive action of the dye liquid as it is forced through the jet. Jet rope washing is a very similar process utilizing water instead of dyestuff. The fabric is not traveling at a very rapid velocity in order to generate any significant force along the longitudinal axis of the fibers within the fabric and possessing very little impact capacity.

Other methods of treating textile fabric include "shot peening", which involves the perpendicular striking of fabric with a wedge or ball shaped device that is similar to "beetling" in which fabric is revolved slowly around a huge wooden drum and pounded with wooden hammers. With both methods, the yarns are flattened to make the weave appear less open than it really is. Shot peening is disclosed in U.S. Patent No. 4,015,317 issued on April 5, 1977 to The Dow Chemical Company. Furthermore, the increased surface area gives more luster, greater absorbency and smoothness. This force, however, is perpendicular to the face of fabric as opposed to being aligned with the longitudinal axis of the fiber.

This invention relates to improved method and apparatus for giving material an aged appearance and more particularly, to provide a method and apparatus for cleaning, abrading, scraping, puncturing or otherwise working fabrics or garments in order to modify the appearance, smoothness, coefficient of friction, handle, drape, and other related fabric proprieties.

In recent years, the commercial process of providing garments, particularly denim, with an aged or distressed appearance has been found to be highly desirable by many consumers. In the past, denim has been commercially faded by subjecting the denim to either a chemical bath or to abrasive particulates or both in combination. A popular method is to use pumice saturated with a bleaching agent. This saturated pumice is added to the wash cycle to obtain an uneven faded or scuffed look which almost passes for natural wear. Numerous variations of this process have been practiced with the use of enzymes or acids instead of bleach as well as ceramics, rubber balls or sand instead of pumice. An example of this is U.S. Patent No. 4,763,100 which discloses pre-formed sand and resin bonded abrasive elements mixed with denim jeans and tumbled within an elongate drum. Another variation is to pretreat the fabric by sand or shot blasting prior to treatment by chemicals or abrasives. This treatment is used to accelerate the aging and distressing of the fabric.

A major problem with the current means of altering fabric texture and appearance is that the large stones used in the process, along with the very abrasive particulate generated during processing, are very deleterious to equipment, and in addition, require manual removal from the processed garments due to the tendency of the smaller particles to accumulate in pockets and interior surfaces.

Another problem is that the washing process itself is very time consuming and increases the cost of manufacturing the garment to a significant degree.

A further problem is that this abrasive washing process is very inexact. Due to the variables involved, the final appearance of the garment is not consistent. Moreover, the combination of chemical and abrasive treatment degrades the fabric strength and reduced the garment life.

The present invention treats fiber and/or fabric in a manner not disclosed in the known prior art with associated unique results.

Summary of the Invention

A method and apparatus is provided for modifying fiber or fabric by fatiguing that creates at least two of the following characteristics including:

1. axially aligned cracks;
2. physical modification of the fiber in the form of either kink banks, enlarged nodes, or enlarged segregated fibril tangles; and
3. increased amount of fibrils present on fiber surface in contrast to unfatigued state.

Fatiguing is defined as repeated stress on fiber by high velocity impact that bends the fiber and compresses it in a direction parallel to the fiber's longitudinal axis. High velocity is defined as requiring the fiber to move at a rate of 50 feet per second or higher.

An apparatus and method for modifying the texture and appearance of material which comprises a closed hollow cylinder having an interior surface with curved wall and a means for material entry and exit to said hollow cylinder and at least one gas jet directed away from the interior of the curved wall of said cylinder and an air exhaust means for said hollow cylinder. The one or more gas jets create a vortex that rapidly and repeatedly cycles the material at low tension past the gas jets. The rapid vibrations generated in the material by the jet(a) serve to break apart fiber to fiber bonds caused by finish and loosen up the structure of the yarns and that of the material.

An advantage of this invention is that the hand of the fabric is noticeably improved, especially, but not limited to fabrics formed of liquid crystal fibers and bast fibers. Furthermore, bending, drape, bulk and surface softness are also noticeably improved.

A second advantage of this invention is that the fiber may be treated in either yarn or fabric form.

A third advantage of this invention, is that there is a relatively minor degradation in strength after treatment.

A fourth advantage of this invention is that when treated, ramie and flax fabrics have a higher strength and softer hand than cotton fabrics of equal weight.

A fifth advantage of this invention that after treatment, HM-aramid fibers are readily dyeable by basic or disperse dyes for medium and dark shades and sulfur dyes for light shades due to increased porosity that allows the penetration of dyestuffs into the HM-aramid fiber or fabric without the need for swelling agents or carriers.

A sixth advantage of this invention is that aromatic polyester can be transformed from a very stiff and unconfortable fabric to a very soft, pliable and supple fabric with an increase in dyeability at the fiber's nodes.

A seventh advantage of this invention is that it treats fabric in both the warp and fill direction as opposed to traditional treatment processes that affect fabric only in the warp direction.

An eighth advantage of this invention is that the desired aged appearance is obtained as wall as a very soft texture that is superior to that which can be obtained by stone washing.

A ninth advantage of this invention is that no abrasives need to be removed from either the materials or equipment after processing, although abrasives can be used as an option.

Yet a tenth advantage of this invention is the minimal time required when contrasted to abrasion or washing processes.

An eleventh advantage of this invention is that the final result is very exact depending on the control of variables such as time and air pressure.

A twelfth advantage of this invention is that the material is not degraded due to combination of chemicals and abrasives.

These and other advantages will be in part apparent and in part pointed out below.

Brief Description of the Drawings

The above as well as other objects of the invention will become more apparent from the following detailed description of the preferred embodiments of the invention, when taken together with the accompanying drawings, in which:

FIG. 1 is a schematicized side view of the apparatus for fatiguing fabric of the instant invention wherein a rope of fabric is treated by a plurality of impact rolls;

FIG. 2 is a side view of the apparatus for fatiguing fabric of the instant invention;

FIG. 3 is a cross-sectional view of the apparatus for fatiguing fabric taken along line 3-3 of FIG. 2;

FIG. 4 is a top plan view of the oscillating assembly utilized in the apparatus for fatiguing fabric of the present invention;

FIG. 5 is a cross-sectional view of the oscillating assembly taken along line 5-5 of FIG. 4;

FIG. 6 is a front view of an impact roll utilized in the apparatus for fatiguing fabric of the present invention;

FIG. 7 is a side view of an impact roll utilized in the apparatus for fatiguing fabric of the present invention;

FIG. 8 is a top view of an alternative embodiment disclosing an apparatus utilized to fatigue yarn;

FIG. 9 is a cross-sectional view of the yarn fatiguing apparatus taken along line 9-9 of FIG. 8;

FIG. 10 is a cross-sectional view of the yarn fatiguing apparatus taken along line 10-10 of FIG. 9;

FIG. 11 is a perspective view of the jet cylinder of the present invention having converging/diverging slots;

FIG. 12 is a side view of a fiber that has been fatigued revealing an increased number of fibrils resulting from shear (abrasion) of the present invention;

FIG. 13 is a side view of a homogenous fiber that has been fatigued revealing kind bands resulting from bending and axial compression of the present invention;

FIG. 14 is a side view of a fiber having nodes or segregated fibular tangles that are actuated and expanded due to fatiguing by bending and axial compression of the present invention;

FIG. 15 is a side view of a fiber that has been fatigued revealing cracks and separation resulting from the fatiguing process of the present invention;

FIG. 16 is a graphical presentation of banding, surface compression, shearing and tensile properties of treated KEVLAR® fabric in contrast to standard polyester fabric by means of the Kawabata evaluation System;

FIG. 17 is a graphical presentation of bonding, surface compression, shearing and tensile properties of treated linen fabric and a treated fabric constructed of 70% ramie and 30% cotton by means of the Kawabata Evaluation system;

FIG. 18 is a photomicrograph of KEVLAR® (para-polyaramid) at 30X magnification prior to being treated by fatiguing;

FIG. 19 is a photomicrograph of KEVLAR® (para-polyaramid) at 30X magnification after being treated by fatiguing;

FIG. 20 is a photomicrograph of KEVLAR® (para-polyaramid) at 100X magnification prior to being treated by fatiguing:

FIG. 21 is a photomicrograph of KEVLAR® (para-polyaramid) at 100X magnification after being treated by fatiguing;

FIG. 22 is a photomicrograph of KEVLAR® (para-polyaramid) at 250X magnification prior to being treated by fatiguing;

FIG. 23 is a photomicrograph of KEVLAR® (para-polyaramid) at 250X magnification after being treated by fatiguing;

FIG. 24 is a photomicrograph of KEVLAR® (para-polyaramid) at 2000X magnification prior to being treated by fatiguing;

FIG. 25 is a photomicrograph of (para-polyaramid) at 2500X magnification after being treated by fatiguing;

FIG. 26 is a photomicrograph of KEVLAR® (para-polyaramid) at 2000X magnification prior to being treated by fatiguing;

FIG. 27 is a photomicrograph of KEVLAR® (para-polyaramid) at 3500X magnification after being treated by fatiguing;

FIG. 28 is a photomicrograph of VECTRAN®-(fully aromatic polyoester) at 100X magnification prior to being treated by fatiguing;

FIG. 29 is a photomicrograph of VECTRAN®-(fully aromatic polyester) at 100X magnification after being treated by fatiguing;

FIG. 30 is a photomicrograph of VECTRAN®-(fully aromatic polyester) at 350X magnification prior to being treated by fatiguing;

FIG. 31 is a photomicrograph of VECTRAN®-(fully aromatic polyester) at 350X magnification after being treated by fatiguing;

FIG. 32 is a photomicrograph of VECTRAN®-(fully aromatic polyester) at 1000X magnification prior to being treated by fatiguing;

FIG. 33 is a photomicrograph of VECTRAN®-(fully aromatic polyester) at 1000X magnification after being treated by fatiguing;

FIG. 34 is a photomicrograph of VECTRAN®-(fully aromatic polyester) at 2000X magnification prior to being treated by fatiguing;

FIG. 35 is a photomicrograph of VECTRAN®-(fully aromatic polyester) at 2000X magnification after being treated by fatiguing;

FIG. 36 is a photomicrograph of ramie at 350X magnification prior to being treated by fatiguing;

FIG. 37 is a photomicrograph of ramie at 350X magnification after being treated by fatiguing;

FIG. 38 is a photomicrograph of ramie at 1000X magnification prior to being treated by fatiguing.;

FIG. 39 is a photomicrograph of ramie at 1000X magnification after being treated by fatiguing;

FIG. 40 is a photomicrograph of ramie at 1000X magnification prior to being treated by fatiguing;

FIG. 41 is a photomicrograph of ramie at 1000X magnification after being treated by fatiguing;

FIG. 42 is a photomicrograph of linen at 350X magnification prior to being treated by fatiguing;

FIG. 43 is a photomicrograph of linen at 350X magnification after being treated by fatiguing;

FIG. 44 is a photomicrograph of linen at 350X magnification prior to being treated by fatiguing;

FIG. 45 is a photomicrograph of linen at 350X magnification after being treated by fatiguing;

FIG. 46 is a photomicrograph of linen at 2000X magnification prior to being treated by fatiguing;

FIG. 47 is a photomicrograph of linen at 2000X magnification after being treated by fatiguing;

FIG. 48 is a structural model of the internal organization of a liquid crystal polymer fiber;

FIG. 49 is a side elevational view of the single vortex assembly and air supply means;

FIG. 50 is a cross-sectional view of a single vortex assembly taken along line 50-50 of FIG. 1 and constructed in accordance with the present invention;

FIG. 51 is a fragmentary front elevational view of a single vortex assembly of FIG. 49 disclosing the cover, cover support plate and a gas jet;

FIG. 52 is a cross-sectional view of one of the gas jets shown in FIG. 49 employed in practicing the present invention; and

FIG. 53 is a cross-sectional view of an alternative embodiment of a dual vortex assembly.

Corresponding reference characters indicate corresponding parts throughout the several views of the drawings.

Detailed Description of the Preferred Embodiment

Fatiguing is defined as repeated stress on fiber by high velocity impact that bends the fiber and compresses it in a direction parallel to the fiber's longitudinal axis. High velocity is defined as requiring the fiber to move at a relative velocity of 50 feet per second or higher. Referring now to FIG. 1, an apparatus for fatiguing fabric is generally indicated by numeral 1. Fabric in rope form 2 is threaded through the apparatus 1 by initially passing through combination guide and idler rolls 10 and 12 mounted on shafts 85 and 86 respectively. The fabric in rope form 2 then passes through an oscillator that is generally indicated by numeral 14 and then through a plurality of guide sleeves formed in plates 102, 105, 108, 111 and 114. There are a series of pads 101, 104, 107, 110 and 113, as shown in FIG. 1, that are adjacent to plates 102, 105, 108, 111 and 114 respectively. Between each pair of guide sleeves, the fabric in rope form 2 passes through a pair of impact rolls, starting with rolls 18 and 19, then rolls 21 and 22, then rolls 24 and 25, and finally rolls 27 and 28. Impact roll 18 is mounted on shaft 87, impact roll 19 is mounted on shaft 88, impact roll 21 is mounted on shaft 89, impact roll 22 is mounted on shaft 90, impact roll 24 is mounted on shaft 91, impact roll 25 is mounted on shaft 92, impact roll 27 is mounted on shaft 93, and impact roll 28 is mounted on shaft 94. As shown in FIG. 1, there are four levels of rolls with each pair of rolls being on the same horizontal plane and vertically aligned with all the other pairs of rolls. The fabric in rope form 2 is first treated by impact rolls 18 and 19, which are rotating in a clockwise direction. Treatment is effected by the compressive forces generated in the fibers comprising the fabric in rope form 2 by the high velocity impact of trapezoidal bars 32 that extend across the lateral width of the impact rolls. This high velocity impact, as previously defined, requires the fibers to move at a relative rate of 50 feet per second or higher. The fibers are bent and compressed in a direction parallel to the longitudinal axis of each fiber. This is also shown in FIGS. 6 and 7 with a typical impact roll generally denoted as A. The shaft is generally denoted as B with an extension C for attaching a pulley thereto. There are two trapezoidal bars 32 on each impact roll A that are located one hundred and eighty degrees apart from each other. The trapezoidal bars are secured to the impact roll A by a series of socket head cap screws 199. Each impact roll is timed so that it rotates ninety degrees out of phase with its paired twin on the same horizontal plane. This results in little or no tension being placed on the fabric in rope form 2. The rotational direction of each subsequent pair of impact rolls is reversed to further insure uniformity of treatment. The fabric in rope form exits the machine by means of guide and idler wheels 34 and 36 that are each mounted on shafts 95 and 96 respectively. A conventional means is used to transport and tension the fabric in rope form 2, which could be a traction roll and dancer combination and variations thereof.

Referring now to FIGS. 2 and 3, which disclose a right side view and front view, respectively of the apparatus 1, comprising of three rectangular frames 80, 81 and 83 joined together. The center rectangular frame 83 has seven horizontal dual members on seven different levels with dual vertical support members 38 and 40. From top to bottom these levels are numerically indicated as 42, 43, 44, 45, 46, 47, and 48 respectively. Combination guide and idler roll 10 is rotatively connected to a pair of bearings 51 on each side. The pair of bearings 51 are attached to a pad 52 that is mounted at the top of vertical side member 40. Combination guide and idler roll 12 is attached to bearings 54 that are attached to dual upper pads 55 that are attached to the first horizontal dual members 42 at the top of frame 83.

The oscillator 14 is mounted on top of the second horizontal dual members 43. Mounted to the second horizontal dual members 43 are lower dual pads 101 that are connected to a lower plate 102 as shown in FIG. 3.

The third horizontal level has impact roll 18 rotatively attached to dual bearing 56 and impact roll 19 is rotatively attached to dual bearings 57. Dual bearings 56 and 57 are attached to upper dual pads 58 that are mounted on the top of the third horizontal dual members 44. On the bottom of the third horizontal dual members are lower dual pads 104 with a lower plate 105 connected thereto by means of conventional hardware or equivalent through to the third horizontal dual members 44.

The identical arrangement is duplicated on the fourth horizontal level with dual bearings 60 for impact roll 21, dual bearings 61 for impact roll 22 with dual bearings 60, 61 attached to upper dual pads 62 mounted to the top of the fourth horizontal dual members 45. On the bottom of the fourth horizontal dual members 45 are lower dual pads 107 with a lower plate 108 connected thereto by means of conventional hardware or equivalent through to the fourth horizontal dual members 45.

The same arrangement is duplicated on the fifth horizontal level with dual bearings 64 for impact roll 24, dual bearings 65 for impact roll 25 with dual bearings 64, 65 attached to upper dual pads 66 mounted to the top of the fifth horizontal dual members 46. On the bottom of the fifth horizontal dual members 46 are lower dual pads 110 with a lower plate 111 connected thereto by means of conventional hardward or equivalent through to the fifth horizontal dual members 46.

Furthermore, the sixth horizontal level has the same arrangement, with dual bearings 68 for impact roll 27, dual bearings 69 for impact roll 28 with dual bearings 68, 69 attached to upper dual gads 70 mounted to the top of the sixth horixontal dual members 47. On the bottom of the sixth horizontal dual members 47 are lower dual pads 113 with a lower plate 114 connected thereto by means of conventional hardware or equivalent through to the sixth horizontal dual members 47.

Guide and idler roll 34 is rotatively connected to dual bearings 72, which are mounted on upper dual pads 73 that are attached to the seventh horizontal dual members 48.

The fabric in rope form 2 then exits the apparatus 1 by means of another guide and idler roll 36 that is rotatively connected to dual bearings 75, which are mounted on plate 76 that is attached to the bottom of vertical side member 38.

The three rectangular frames 80, 81, and 83 are connected to a lower horizontal support frame 117 with support pads 316 interposed therebetween. The lower horizontal support frame 117 is supported by four vibration isolation pads 118.

Rectangular frame 80, shown to the right of rectangular frame 83 in FIG. 3, has a top member 121 that is connected to rectangular frame 83 by means of an angle bracket 122 and bolts, or other equivalent attachment means such as welding, adhesives, and so forth as is typical of all bolt attachments throughout this application. The middle member 125 of rectangular frame 80, which is on the same horizontal plane as the fifth horizontal dual members 46 of rectangular frame 83, supports a motor 127 by means of a motor support frame 128. The motor 127 has a pulley 130 connected to it that drives a belt 131 that rotates a pulley 132 connected to impact roll 22 by means of shaft 90 through bearing 61 and pulley 133 connected to impact roll 21 by means of shaft 89 through bearing

60. The impact rolls 18, 19, 21, 22, 24, 25, 27, 28 throughout this application are preferable twelve inches in diameter with the preferred impact roll speed of 5,000 revolutions per minute, although these values can vary with the consideration that the fabric in rope form 2 must go into compression during impact with the bars 32, rather than simple buckling or bending. The motors 127, 137, 153 and 162 can be electric, pneumatic, combustion and so forth. About 25 horsepower per pair of impact rolls is required for most fabrics in order to move the fabric at a rate of 50 feet per second or higher. By using apparatus 1, compression can be imparted to the filling as well as the warp yarns along the longitudinal axis of the respective fibers. The lower member 135 of rectangular frame 80, which is on the same horizontal plane as the seventh horizontal dual members 48 of rectangular frame 83, supports a motor 137 by means of a motor support frame 138. The motor 137 has a pulley 140 connected to it that drives a belt 141 that rotates a pulley 142 connected to impact roll 28 by means of shaft 94 through bearing 69 and pulley 143 connected to impact roll 27 by means of shaft 93 through bearing 68.

Rectangular frame 81, is on the opposite side of rectangular frame 83 from rectangular frame 80 as shown in FIG. 3, has a top member 145 that is connected to rectangular frame 83 by means of an angle bracket 146 and bolts, or other equivalent attachment means. The first middle member 148 of rectangular frame 81, which is on the same horizontal plane as the fourth horizontal dual members 45 of rectangular frame 83, supports a motor 133 by means of a motor support frame 154. The motor 153 has a pulley 156 connected to it that drives a belt 157 that rotates a pulley 158 connected to impact roll 19 by means of shaft 88 through bearing 57 and pulley 159 (not shown) that is similar to pulley 158 connected to impact roll 18 by means of shaft 87 through bearing 56. The second middle member 150 of rectangular frame 81, which is on the same horizontal plane as the sixth horizontal dual members 47 of rectangular frame 83, supports a motor 162 by means of a motor support frame 163. The motor 162 has a pulley 165 connected to it that drives a belt 166 that rotates a pulley 167 connected to impact roll 25 by means of shaft 92 through bearing 65 and pulley 168 (not shown) that is similar to pulley 167 connected to impact roll 24 by means of shaft 91 through bearing 64. There is a lower member 151 of rectangular frame 81, which is on the same horizontal plane as the seventh horizontal dual members 48 of rectangular frame 81, which is used for structural support.

Referring now to FIGS. 4 and 5, the fabric oscillator is generally indicated by numeral 14. The fabric in rope form 2 is nipped between a pair of rubber covered nip rolls 170 and 171, rotatably mounted on central shafts 200 and 201, which have a hole in each opposing end that slide over dual opposing shafts 172 and 308. The dual opposing shafts 172 and 308 have hexagonal nuts 174 on each end of each shaft 172 and 308 with dual springs 173 that put pressure against the opposing ends of the central shafts 200 and 201 with pads 176 therebetween. The pads 176 are rigidly fixed to the rotatably mounted oscillating disk 206, as also shown in FIG. 3, that is rotated through a fixed angle by a conventional actuator 177 that is rotatably attached by means of bearing and shaft arrangement 178. The oscillating disk 206 is rotatable mounted to a stationary platform 180 by means of large diameter bearings 182. The opposite end of the actuator 177 is pivotally connected to the stationary platform 180 by means of bearing and shaft combination 185. The stationary platform 180 is mounted on upper dual pads 187 that are attached to the second level horizontal dual members 43.

Fabric may be fatigue treated by means of impact with bars mounted to the exterior of a cylinder rotated at high speeds of over 50 feet per second. The fabric is treated in the form of rope to reduce the required width of the treatment rolls due to the high amount of rotational kinetic energy stored in these rolls and because of the fact that in rope form, the fabric can be treated in both the warp and fill direction simultaneously. Each individual fiber is bent and compressed in a direction parallel to the fiber's longitudinal axis

Referring now to FIGS. 6 end 7, which discloses a front and side view of a typical impact roll denoted as A with a shaft B with an extension C for attaching a pulley thereon. There are dual flange members 197, which serve the function of affixing the impact roll A to the shaft B. Furthermore, there are circular cover plates 193 mounted on each aide of the impact roll A.

Another means to fatigue fabric is by application of one or more gas jets directed away from the interior curved surface of a cylinder, generating a vortex that rapidly and repeatedly cycles the substrate at low tension past the gas jets. The rapid vibrations generated in the substrate by the jets serve to break apart fiber to fiber bonds caused by finish and loosen up the structure of the yarns and that of the substrate. Impact of the fabric with the walls of the cylinder repeatedly flexes and axially compresses the fibers, inducing fatigue. This creates a desired aged appearance as well as a very soft texture. This apparatus and method is disclosed in U.S. Patent Application No. 07/596,271, filed october 12, 1990, which is incorporated herein by reference and entitled "METHOD AND APPARATUS FOR MODIFICATION OF TEXTURE AND APPEARANCE OF MATERIALS" and also having the same sole inventor.

Referring now to FIGS. 8, 9, 10 and 11, an apparatus to fatigue yarn is generally indicated by numeral 201. Yarn 202 is threaded through the apparatus 201 into the top opening 241 along the centerline 201 and is rapidly cycled against the walls of a jet cylinder 207 located between a lower spacer cylinder 208 and an upper spacer cylinder 209. This structure is mounted between a lower tapered end cap 210 and an upper tapered end cap 211. The yarn is then removed through a bottom opening 242. The apparatus 201 is substantially a cylindrical structure with tapered ends.

The main mechanisms for fatiguing are dual lower converging/diverging slots 217 and 218 and dual upper converging/diverging slots 215 and 216. In FIG. 9, upper converging/diverging slot 215 and lower converging/diverging slot 217 are shown. Converging/diverging slot 216 is located one hundred and eighty degrees from converging/diverging slot 215 on the same horizontal plane and converging/diverging slot 218 is located one hundred and eighty degrees from converging/diverging slot 217 on the same horizontal plane, as shown in FIG. 10. Slots 215, 216, 217 and 218 direct air tangentially to the inside of the apparatus 201. The rapidly rotating air follows helical path 290 and helical path 291, as shown in FIG, 10. The tapered bore of end caps 210 and 211 allow air to exhaust only after it has lost most of its initial circumferential velocity. Air is delivered to said converging/diverging slots 215, 216, 217, and 218 by pneumatic tubes 223 and 224 that attach to "L" shaped threaded fittings 226 and 227 that attach to the main cylindrical body 229 of the apparatus 201. The main cylindrical body 229 is formed around the jet cylinder 207, lower spacer cylinder 208, and upper spacer cylinder 209 and functions as an outer shell. "L" shaped threaded fitting 226 is attached to main cylindrical body 229 and delivers air to converging/diverging slots 217 and 218, as shown in FIG. 10. There is a connecting chamber 247 in the main cylindrical body 229 to provide air from the "L"- shaped threaded fitting 226 to a circular conduit 232 formed by an indentation in the outer edges of the bottom of jet cylinder 207 and a matching indentation in the outer edges of the top of lower spacer cylinder 208. The converging/diverging slots 217 and 218 are formed in the indented projecting circular extension 250, as shown in FIGS. 10 and 11.

Furthermore, the same structure is duplicated with regard to "L"-shaped threaded fitting 227 that is attached to main cylindrical body 229 and delivers air to converging/ diverging slots 215 and 216, as shown in FIG. 9. There is a connecting chamber 303 in the main cylindrical body 229 to provide air from the "L"-shaped threaded fitting 227 to a circular conduit 231 formed by an indentation in the outer edges of the top of jet cylinder 207 and a matching indentation in the outer edges of the bottom of upper spacer cylinder 209. The converging/diverging slots 215 and 216 are formed in the indented projecting circular extension 238, as shown in FIG 11.

The upper tapered end cap is attached to the top of the main cylindrical body 229 by four hexagonal bolts 234 or other mechanical means and the lower tapered end cap 210 is attached by four hexagonal bolts 236 to the bottom of the main cylindrical body 229 in a similar manner.

Actor fatigue treatment, there are three possible characteristics that the fiber and/or fabric will exhibit. The first characteristic is the presence of fibrils due to shear and/or abrasion present in the fatiguing process. Fibrils are defined as one of the minute fibrous elements making up a fiber. Fibrous is defined as containing, consisting of, or like fibers. This is shown in FIG. 12. The second characteristic is the presence of physical change created by the bending and compression of the fiber along the fiber's longitudinal axis. For relatively homogenous fiber like KEVLAR®, kink bands generated by bending or compression occur randomly along the fiber. For fibers which are axially nonuniform, such as those fibers which exhibit nodes, the compressive and bending stresses will not be random, but rather will correspond to the weakest areas of the fiber. For bast fibers, the weakest points are the so called growth nodes, which are accentuated and expanded by the treatment. For VECTRAN®, the weakest points are nodes which are believed to be areas of segregated fibular tangles. These areas are similarly expanded and are typified by FIG. 14. The third characteristic is cracks in the fiber due to fatigue, as shown in FIG. 15. These cracks are defined as axial separations in the fiber, and are believed to be the cause of the node enlargement described above. This third characteristic is the most important in enhancing both hand and dyeability.

A type of yarn or fabric in which the hand and dyeability are improved by repeated stress on fiber by high velocity impact that bends the fiber and compresses it in a direction parallel to the fiber's longitudinal axis is a liquid crystal fiber. This includes both lyotropic and thermotropic liquid crystal fibers. One type of thermotropic liquid crystal fiber, among others, is a fully aromatic polyester and one type of a lyotropic liquid crystal fiber, among others, would be an aromatic polyamide (polyaramid).

A mere illustrative example of an aromatic polyamide would be high modulus aramid fibers such as poly(para-phenylene terephthalamide) such as KEVLAR® manufactured by E. I. du Pont Nemours and Co.

FIG. 18 is a photomicrograph at 30X magnification of KEVLAR® fibers prior to fatigue treatment. FIG. 19 is a photomicrograph at 30x magnification of KEVLAR® fibers after fatigue treatment. The high degree of fibrillation in FIG. 19 presents a marled contrast to FIG. 18.

FIG. 20 is a photomicrograph at 100X magnification of KEVLAR® fibers prior to fatigue treatment, FIG. 21 is a photomicrograph at 100x magnification of KEVLAR® fibers after fatigue treatment. This again, demonstrates the contracting degree of fibrillation.

FIG. 22 is a photomicrograph at 290X magnification of KEVLAR® fibers prior to fatigue treatment with the ends thereof prominently displayed. FIG. 23 is a photomicrograph at 250x magnification of KEVLAR® fibers after fatigue treatment focusing again on the ends of the fibers. The degree of fibrillation is again contrasted.

FIGS. 24 and 26 are photomicrographs at 2000X magnification of KEVLAR® fibers prior to fatigue treatment, FIGS. 25 and 27 are photomicrographs at 2500x and 3500x, respectively, magnification of KEVLAR® fibers after fatigue treatment.

FIGS. 25 and 27 reveal all three characteristics including fibrils, kink bands and cracks.

Few fibers are broken during treatment, therefore there is only a small decrease in tensile strength of the fabric. Typically, tensile strength is reduced by ten percent (10%) or less. The greater mobility and flexibility of the fibers after treatment contribute not only to a soft hand, but also to an improvement is cut resistance.

Similar treatment of fabrics composed of other polymers such as standard polyester or nylon shows neither the same magnitude of improvement of hand nor the concomitant improvement in dyeability nor the microscopic evidence of cracks, kink bands or fibrillation. In FIG. 16, results from twelve tests relates to hand are reported for a filament KEVLAR® fabric and for a standard filament polyester fabric. These twelve tests are part of the Kawabata Evaluation System for Fabrics (KESF) and are conveniently divided into five test groups: bending, surface, compression, shearing and tensile. The nature of the tests and units used can be briefly described as follows:

The bending properties are "B" - the bending stiffness in gf-cm^2/cm and "2HB" - the bending hysteresis at @ 0.9 cm^{-1} in gf-cm/cm. Hysteresis is a measure of the energy lost during deformation, representing a lack of recovery.

The surface properties are "MIU"- the coefficient of friction, "MMD" - the mean deviation of the coefficient of friction, and "SMD" - the mean deviation in surface roughness in micrometers.

The compression properties are "W" - the weight in mg/cm^2, "T" - the thickness in millimeters at a compressive pressure of 0.5 gf/cm^2, "RC" - the compressional resilience in percent, "WC" - the energy in gf-cm/cm^2 to compress the sample to a surface pressure of 50 gm/cm^2, and "LC" - compressional linearity.

The shear properties are "G" - shear stiffness in gf/cm-degree and "2HG" - shearing hysteresis at 0.5° gf/cm.

The tensile properties are "EMT" - the extensibility in percent at the 500 gf/cm level, "LT" - the tensile linearity, "WT" - the tensile energy in gf-cm/cm, and "RT" - the tensile resilience in percent.

For both the KEVLAR® and standard polyester samples, data is shown in dimensionless form by dividing the results for the treated sample by that for the untreated control. The two most important tests that apply to what is generally considered to be the "drape" of a fabric are the bending stiffness "B" and the shear stiffness "G". In the case of the KEVLAR® sample, the bending stiffness has been reduced by the treatment by a factor of nearly ten and the shear stiffness has been reduced by a factor of about 2.5.

A mere illustrative example of a fully aromatic polyester fiber is VECTRAN® manufactured by Hoechst Celanese Corporation.

FIG. 28 is a photomicrograph at 100X magnification of VECTRAN® fibers prior to fatigue treatment. FIG. 29 is a photomicrograph at 100x magnification of VECTRAN® fibers after fatigue treatment. The high degree of fibrillation and expansion occurring at the nodes in FIG. 29 presents a marked contrast to FIG. 28.

FIG. 30 is a photomicrograph at 350X magnification of VECTRAN® fibers prior to fatigue treatment. FIG. 31 is a photomicrograph at 350x magnification of VECTRAN® fibers after fatigue treatment. The high degree of fibrillation and expansion occurring at the nodes in FIG. 31 again presents a marked contrast to FIG. 30.

FIG. 32 is a photomicrograph at 1000X magnification of VECTRAN® fibers prior to fatigue treatment. FIG. 33 is a photomicrograph at 1000x magnification of VECTRAN® fibers after fatigue treatment. The high degree of fibrillation and expansion as well as cracking occurring at the nodes in FIG. 33 again presents a marked contrast to FIG. 32, only these photomicrographs present much sharper detail than the previous four photomicrographs.

FIG. 34 is a photomicrograph at 2000X magnification of VECTRAN® fibers prior to fatigue treatment. FIG. 35 is a photomicrograph at 2000x magnification of VECTRAN® fibers after fatigue treatment. The high degree of fibrillation and expansion as well as cracking occurring at the nodes in FIG. 35 again presents a marled contrast to FIG. 34, only these photomicrographs present much sharper detail than any of the previous VECTRAN® photomicrographs.

Again, few fibers are broken during treatment, therefore there is only a small decrease in tensile strength of the fabric. Typically, tensile strength is reduced by ten percent (10%) or less. The greater mobility and flexibility of the fibers after treatment contribute not only to a soft hand, but also to an improvement in cut resistance. Furthermore, the nodal areas are rendered dyeable by the treatment.

A type of fabric whose hand is noticeable improved by the fatiguing process, defined as repeated stress on fiber by high velocity impact that bends the fiber and compresses it in a direction parallel to the fiber's longitudinal axis, is one composed of natural fibers. Natural fibers woven into fabric, are already dyeable to a significant degree so that the fatiguing process has relatively little effect on this aspect. The most widely used natural fibers are the vegetable fibers, which may be classified into four groupe, all of which are predominately cellulosic. These groups are: seed fibers such as cotton and kapok, fruit fibers such as coir, leaf fibers such as abaca, alfa, sisal, henequen and maguey, and bast fibers much as linen (flax), ramie, hemp, jute, kenaf, and sunn.

Of the bast fibers, ramie and linen are of particular interest because both are hard wearing, very strong fibers. Linen, for example, is approximately twice as strong as cotton, while ramie is about twice as strong as linen. Furthermore, ramie becomes considerably stronger when wet. Chemically, ramie and linen are virtually identical to cotton and therefore take up dye and finishes in the same manner as cotton. The major limitation of these fibers heretofore has been the stiffness of the resultant fabrics as compared to similar fabrics manufactured of cotton. Ramie and linen fibers used in fabrics typically have diameters of two to five times that of cotton fibers. Since the stiffness of a fiber varies as the fourth power of its diameter, it is easily seen that fabrics constructed of ramie and linen will have limited utility when soft hand is required. In addition, the large diameter of ramie and linen fabrics can result in an inherent sensitivity to bending. It is said that ramie fabric can break if folded repeatedly along the same line.

Bast fibers with the exception of ramie, are composed of multiple fiber cells. A fiber of linen, for example, is composed of ten to fourteen individual ultimate fibers. These ultimate fibers generally have diameters smaller than that of cotton. Ramie fibers generally appear to be unicellar, however, the very linear nature of these fibers allows fatigue treatment to create axially aligned cracks and fibrillation in a manner analogous to that produced in para-aramids. Linen, because of its multicellular structure, is even more susceptible to treatment. The other bast fibers, while also susceptible to treatment, have ultimate fiber lengths that are too short to remain in the yarn after separation.

Linen and ramie fabrics, after fatigue treatment, contain a substantial portion of fibers of a diameter smaller than that of cotton and can exhibit a soft hand considerably softer than that of a cotton fabric of equal weight.

FIGS. 36 and 37 are photomicrographs at 350X magnification of ramie fibers before and after fatigue treatment, respectively. The ultimate fibrils are either distinct or loosely bonded to the original structure in FIG. 37, which presents a marked contrast to the monolithic structure of the relatively large diameter fibers in FIG. 36.

FIG. 38 is a photomicrograph at 1000X magnification of ramie fibers prior to fatigue treatment. FIG. 39 is a photomicrograph at 1000x magnification of ramie fibers after fatigue treatment. FIGS. 39 reveals two of the three characteristics typical of the treatment including fibrils and numerous cracks.

FIG. 40 is a photomicrograph at 1000X magnification of ramie fibers prior to fatigue treatment. FIG. 41 is a photomicrograph at 1000x magnification of ramie fibers after fatigue treatment. FIGS. 41 reveals fibrils and numerous cracks in much the same way as FIG. 39.

FIGS. 42 and 43 are photomicrographh at 350X magnification of linen fibers before and after fatigue treatment, respectively. In FIG 43, the fibers exhibit a profuse number of attached fibrils that appear to be of a cellular or subcellular size. As is typical in this treatment, no broken fiber ends are apparent.

FIGS. 44 and 45 are photomicrographs at 350X magnification of linen fibers before and after fatigue treatment, respectively. The ultimate fibrils are either distinct or loosely bonded to the original structure in FIG. 45, which presents a marked contrast to the monolithic structure of the relatively large diameter fibers in FIG. 44.

FIG. 46 is a photomicrograph at 2000X magnification of linen fibers prior to fatigue treatment with the ends thereof prominently displayed. FIG. 47 is a photomicrograph at 2000x magnification of linen fibers after fatigue treatment focusing again on the ends of the fibers. The degree of separation and cracking again provides for a marked contrast.

In FIG. 17, results from twelve teats related to hand are reported for both a linen fabric and for a seventy (70) percent ramie and thirty (30) percent cotton fabric. These twelve tests arm part of the Kawabata Evaluation system for Fabrics (KESF) and are conveniently divided into five teat groups: bending, surface, compression, shearing and tensile. The nature of the tests and units used are describeb on Pages 28 and 29, but for completeness of this disclosure are reiterated as follows:

The bending properties are "B" - the bending stiffness in gf-cm^2/cm and "2HB" - the bending hysteresis at @ 0.9 cm^{-1} in gf-cm/cm. Hysteresis is a measure of the energy lost during deformation, representing a lack of recovery.

The surface properties are "MIU"- the coefficient of friction, "MMD" - the mean deviation of the coefficient of friction, and "SMD" - the mean deviation in surface roughness in micrometers.

The compression properties are "W" - the weight in mg/cm^2, "T" - the thickness in millimeters at a compressive pressure of 0.5 gf/cm^2, "RC" - the compressional resilience in percent, "WC" - the energy in gf-cm/cm^2 to compress the sample to a surface pressure of 50 gf/cm^2, and "LC" - compressional linearity.

The shear properties are "G" - shear stiffness in gf/cm-degree and "2HG" - shearing hysteresis at 0.5° gf/cm.

The tensile properties are "EMT" - the extensibility in percent at the 500 gf/cm level, "LT" - the tensile linearity, "WT" - the tensile energy in gf-cm/cm, and "RT" - the tensile resilience in percent.

For both the linen and ramie/cotton samples, data is shown in dimensionless form by dividing the results for the treated sample by that form the untreated control. The two most important tests that apply to what is generally considered to be the "drape" of a fabric arc the bending stiffness "B" and the shear stiffness "G".

FIG. 48 is the structural model commonly accepted as representative of the internal structure of liquid crystal polymer fibers. In the case of lyotropic liquid crystal fibers such as KEVLAR® fatigue treatment is believed to generate major cracks between the so called macro fibrils, some of which are pulled free from the surface. Smaller cracks at various levels of the structure are believed to provide access for dyestuff and are believed to be responsible for decreasing the bending stiffness of the fiber. In the case of thermotropic liquid crystal fibers, natural disruptions in the linear organization of the structure at various levels due to tangles of macro fibrils or fibrils are believed to occur. These areas segregate out into quasi-periodic nodes, having a superficial resemblance to the growth nodes occurring in bast fibers, during spinning or subsequent heat-treating. Stresses generated during fatigue treatment predominately act on these areas, since they are weaker in compression than the bulk fiber. FIGS. 33 and 35 show fibrils which appear to be anchored into the swollen nodes.

Referring now by reference numerals to the drawings, and first to FIGS. 49-53, a single vortex material treatment assembly is indicated generally by numeral 510. This assembly 510 comprises a hollow cylinder 512, the curved wall of which is defined by curved plates 513, top plates 540 and base plates 542, as shown in FIGS, 49, 50 and 51. The curved plates 513 of the hollow cylinder 512, as well as all other components of the present invention not delineated to the contrary, can be constructed out of a variety of materials such as various metals, durable plastics, ceramics and so forth with the preferred material being steel. There are four gas jet assemblies, indicated generally as numeral 520 spaced at equal distances from each other along the circumference of the hollow cylinder 512.

As shown in FIG. 49, gas is supplied to the gas jet assemblies by gas hoses 522, preferable constructed out of rubber or any flexible material that can carry gas at high pressure. The gas hoses 522 are attached over a tube inlet 524 to provide gas into the gas jet assembly 520. Each hose 522 connects to a single distribution manifold 526 which supplies gas from a second larger gas supply line 528. This distribution manifold 526, a conventional gas tube interconnection, is attached to the support frame 530 that is for the entire assembly 510.

Referring now to FIG. 52, 532 is supplied from tube inlet 524 into the manifold 532 that supplied pressurized gas to through passage 534 which communicates with submanifold 536 that ejects the gas-by means of a converging/diverging nozzle 538. This converging/diverging nozzle 538 is formed by top plate 540 and base plate 542. Both of these plates 540 and 542 are attached to the curved plates 513 by means of locking screws 544 and 546 respectively. The top plate 540 is fastened to the base plate 542 by means of screw 548. The manifold 532 is fastened to the base plate 542 by means of screw 550. Any equivalent structure which creates a gas nozzle tangential to the interior of the curved surface may be used.

Referring now to FIG. 50, the gas jet assembly propels gas at a direction substantially tangential to the interior surface of the hollow cylinder 512 as shown by numeral 552. The gas used is typically air compressed to 30 p.s.i., however, depending on the sensitivity of the textile fabric to be treated, this pressure can be varied between 5 to 120 p.s.i. It is found that this process is most effective when the air used to treat the garments is heated substantially above room temperature. It has been found that 350 degrees Fahrenheit is the practical limit for most textile fabrics.

As shown in FIGS. 50 and 51, the gas jet assemblies 520 serve the dual purpose of propelling the fabric 554 around the inside of the hollow cylinder 512 and simultaneously vibrating the garment as it passes over the nozzle 538. The fabric 554 is treated four times each revolution as it is driven clockwise within the hollow cylinder 512 at a rate of about 25 revolutions per second. The fabric 554 makes a combined sliding, impacting, and rolling motion while traversing the interior surface of the cylinder 512, which defined the outer perimeter of the vortex. The tangential gas lines indicated by 552 flow at sonic velocity or even higher. Exhaust air, lint and other debris escape through the central port 556.

When the material 554 comes in contact with the tangential gas jets 552, it will cause the material 554 to vibrate violently. These vibrations take the form of sawtoothed waves that travel rapidly down the material 554 with small bending radii and high speed combining to break apart fiber to fiber bonds created by finish or sizing.

In addition, the structure of the material 554 is loosened as well as any component yarn that may be present in the material 554. With enough treatment, the material 554 can disintegrate back to its original state of loose fibers.

The curved plates 513 are restrained against the radially directed force generated by the rapidly cycling material 554 by blocks 574 that are fastened to both a front support plate 594 and a back support plate 533 by dual bolts 576. The back support plate 533 is attached to the support frame 530. There is a bolt 580 perpendicular to the curved plate 513 which locks said plate 513 in a fixed location. There are two sets of four of these blocks 574 equidistantly spaced around the circumference of the hollow cylinder 512.

Referring now to FIG. 51, the front support plate 594 is attached to the base plate 542. A cover 590 is attached by a hinge 596 to the front support plate 594. There is also a latch 598 which can fasten the cover 590 to the front support plate 594 and is located on the opposite side of the cover 590 from the hinge 596. The cover 590, in the preferred embodiment, has a viewing port 591 constructed out of glass, plastic or similar material.

In addition to the direct action of the gas jets, the material 554 is treated by a combination of rolling, sliding and impacting with the walls of hollow cylinder 512. It can be appreciated that is the smooth surface of these walls is broken up by the placement of knobs, abrasive material or protrusions, the ageing process will be greatly accelerated. small particles, such as small metal balls, wire portions, rubber, plastic, or wood and so forth, when added to the cylinder 512 will accelerate to a higher speed than the material 554. The relative velocity of small metal particles will be high enough to cause the particles to completely penetrate the material 554 giving it a "buckshot" appearance. Similarly, adding sand to the vortex will give material 554 a "sandblasted" look.

An aspect of this invention to consider is that metal parts such as buttons and zippers can be destroyed by this process in a few seconds. Furthermore, burrs raised by metal to metal impacts can loosen seams in the material 554. Covering the inside of the hollow cylinder 512 with rubber or its equivalent, alleviates this problem. Alternatively, buttons or zippers may be added to the garment after treatment.

In the alternative, a second hollow cylinder 514, which is a mirror image of the first hollow cylinder 512, can be attached to intersect and provide common area 563, as shown in FIG. 53. This prevents roll-up and tangle of the material 554 by reversing the direction of rotation of the material 554 once each cycle. The air supply in each hollow cylinder 512 and 514 is equal, so there is very little transfer of air from one vortex to another without the material 554 present. The material 554 is pressed against the interior of the cylinder 512 by centrifugal force. When the material 554 enters the common area 563, it is no longer coerced by the cylinder wall 512 to cycle in the first vortex. The material 554 continues on a tangent directly into the second vortex of hollow cylinder 514 and then cycles back to the first vortex of hollow cylinder 512 after completing a figure eight pattern. Any rotation in the vortex of hollow cylinder 512 is undone by counter rotation in the vortex of hollow cylinder 514. Each hollow cylinder 512, 514 has a port 560 and 561 respectively, to allow for the escape of excess air, lint or debris.

It is not intended that the scope of the invention be limited to the specific embodiment illustrated and described. Rather, it is intended that the scope of the invention be defined by the appended claims and their equivalents.

Claims

1. A method for altering the physical characteristics of one or more textile fibers or of a yarn having one or more textile fibers each fiber having a longitudinal axis which comprises fatiguing by bending and compressing at least one of said fibers in a direction parallel to said longitudinal axis of at least one of said fibers.

2. A method as claimed in Claim 1, wherein a plurality of textile fibers are woven or knitted together.

3. A method as claimed in Claims 1 or 2, wherein the step of fatiguing comprises impacting said textile fibers with one or more rotating members each having one or more protrusions thereon.

4. A method as claimed in Claim 3, wherein said rotating member is a cylindrical roll.

5. A method as claimed in Claims 3 or 4, wherein the or each said protrusion is a trapezoidal bar.

6. A method as claimed in Claim 3, further comprising two protrusions on the or each said rotating member spaced in a range of ninety to two hundred and seventy degrees apart from each other.

7. A method for altering the physical characteristics of a textile fabric which comprises impacting a moving web of textile fabric with a plurality of cylindrical rolls each having two protrusions thereon.

8. A method as claimed in Claim 7, wherein the textile fabric is in the form of rope.

9. A method as claimed in Claims 7 or 8, wherein the plurality of cylindrical rolls are arranged in parallel sets of two with said moving textile fabric moving therebetween.

10. A method as claimed in Claim 9, wherein the parallel sets of two cylindrical rolls are vertically aligned.

11. A method for improving the dyeability of textile material which comprises impacting a moving web of textile fabric with a plurality of vertically aligned dual sets of rotating cylindrical rolls having two trapezoidal bars mounted on each of said

rolls and spaced between ninety and two hundred and seventy degrees apart by moving said moving web of textile fabric between said dual sets of rotating cylindrical rolls.

12. A method as claimed in Claim 11, further comprising a step of oscillating said fabric prior to said step of impacting said fabric.

13. A method as claimed in Claim 12, wherein said step of oscillating said fabric comprises moving said fabric through an oscillating disk.

14. A method as claimed in Claim 13, wherein said oscillating disk is moved through a fixed angle by means of an actuator.

15. A method as claimed in Claim 14, further comprising a step of nipping said fabric prior to said step of oscillating said fabric.

16. A method as claimed in Claim 15, wherein said step of nipping includes moving said fabric between a pair of rotatably mounted rollers.

17. A method as claimed in Claim 1, wherein the step of fatiguing is carried out utilizing a chamber with inner walls and comprises impacting said textile fiber or said-yarn against the inner walls of the chamber.

18. A method as claimed in Claim 17, wherein said step of impacting said textile fiber or said yarn against the inner walls of the chamber is by means of one or more gas jets directed away from the inner walls.

19. A method as claimed in Claim 18, wherein the gas jets are directed tangentially to said inner walls.

20. A method as claimed in Claim 19, wherein the gas jets are provided in pairs directed substantially tangentially to said inner walls.

21. A method as claimed in Claim 20, wherein a first pair of gas jets and a second pair of gas jets are provided in substantially aligned relation.

22. A method as claimed in Claim 21, wherein a first pair of substantially opposing gas jets and a second pair of substantially opposing gas jets are vertically aligned within said chamber.

23. A method as claimed in Claim 17, wherein said chamber is substantially cylindrical having a first end portion and a second end portion with a first tapered opening is said first end portion and a second tapered opening in said second end portion.

24. A method as claimed in Claim 18, wherein said gas jet or jets include a converging diverging slot.

25. A method as claimed in Claim 18, wherein said textile fiber or said yarn is overfed into said chamber.

26. An apparatus for altering the physical characteristics of a textile yarn which comprises:

(a) a chamber having an interior surface with curved walls;

(b) means for entry and exit to said chamber; and

(c) at least one gas jet directed away from the interior of the curved wall.

27. The apparatus according to Claim 26, wherein each said gas jet is directed substantially tangential to the interior curved walls of said chamber.

28. The apparatus according to Claim 26 or 27, wherein said means for entry and exit to said chamber are tapered.

29. The apparatus according to Claim 26, wherein one or more pairs of substantially opposed gas jets are provided.

30. The apparatus according to Claim 29, wherein a first pair of substantially opposed gas jets and a second pair of substantially opposed gas jets are substantially vertically aligned within said cylindrical chamber.

31. The apparatus according to Claim 30, wherein said gas jets include converging/diverging slots.

32. An apparatus for altering the physical characteristics of a moving web of textile fabric which comprises:

(a) a frame;

(b) a first member having an exterior surface and a longitudinal axis and rotatively connected to said frame;

(c) a rotating second member having an exterior surface and a longitudinal axis and operatively connected to said frame;

(d) a first protrusion on said exterior surface of said first member and a second protrusion on said exterior surface of said second member; and

(e) a means to rotate said first member and second member and operatively attached thereto.

33. An apparatus for altering the physical characteristics of a moving web of textile fabric which comprises:

(a) a frame;

(b) a first member having an exterior surface and a longitudinal axis and rotatively connected to said frame;

(c) a rotating second member having an exterior surface and a longitudinal axis and operatively connected to said frame;

(d) a first protrusion on said exterior surface of said first member and a second protrusion on said exterior surface of said second member;

(e) a first means to rotate said first member and operatively attached thereto; and

(f) a second means to rotate said second member and operatively attached thereto.

34. An apparatus according to Claim 32, wherein said first member comprises a first cylindrical roll and said second member comprises a second cylindrical roll.

35. An apparatus according to Claim 34, wherein said first protrusion is a first trapezoidal bar mounted laterally across said exterior surface of said first cylindrical roll and parallel to said longitudinal axis of said first cylindrical roll and said second protrusion is a second trapezoidal bar mounted laterally across said exterior surface of said second cylindrical roll and parallel to said longitudinal axis of said second cylindrical roll.

36. The apparatus according to Claim 34, wherein said longitudinal axis of said first cylindrical roll is parallel and in substantially the same horizontal plane to said longitudinal axis of said second cylindrical roll.

37. The apparatus according to Claim 32, wherein said means to rotate said first and second cylindrical rolls comprises an electric motor having a rotor with a first pulley mounted thereto that rotatively connects to a second pulley connected to said first cylindrical roll and a third pulley connected to said second cylindrical roll by means of an endless belt.

38. An apparatus for altering the physical characteristics of a moving web of textile fabric which comprises:

(a) a frame;

(b) a plurality of sets of cylindrical rolls including a first cylindrical roll having a longitudinal axis and a second cylindrical roll having a longitudinal axis wherein said longitudinal axis of said first cylindrical roll is substantially parallel to the longitudinal axis of said second cylindrical roll and each set of first and second cylindrical rolls are traverse to each other;

(c) a first means for rotatively attaching said first cylindrical roll to said frame;

(d) a second means for rotatively attaching said second cylindrical roll to said frame; and

(e) a means for rotating said first cylindrical roll and said second cylindrical roll.

39. An apparatus for altering the physical characteristics of a moving web of textile fabric which comprises:

(a) a frame;

(b) a plurality of sets of cylindrical rolls including a first cylindrical roll having a longitudinal axis and a second cylindrical roll having a longitudinal axis wherein said longitudinal axis of said first cylindrical roll is substantially parallel to the longitudinal axis of said second cylindrical roll and each set of first and second cylindrical rolls are traverse to each other;

(c) a first means for rotatively attaching said first cylindrical roll to said frame;

(d) a second means for rotatively attaching said second cylindrical roll to said frame;

(e) a first means for rotating said first cylindrical roll; and

(f) a second means for rotating said second cylindrical roll.

40. The apparatus according to Claim 38, wherein means to rotate said first and second cylindrical rolls comprises a motor having a rotor with a first pulley mounted thereto and a second pulley is connected to said first cylindrical roll and a third pulley is connected to said second cylindrical roll and said first pulley and said second pulley and said third pulley are interconnected by means of an endless belt.

41. The apparatus according to Claim 38, further comprising a means for oscillating said textile material.

42. The apparatus according to Claim 41, wherein said means for oscillating said textile material includes a disk that is rotatably mounted to said frame by an actuator.

43. The apparatus according to Claim 42, wherein said disk is rotatably mounted to said frame by means of bearings.

44. One or more textile fibers that have been treated in accordance with the process of Claim 1 selected from the group consisting of cellulosic vegetable fibers, bast fibers and liquid crystal fibers.

45. A bast fiber according to Claim 44, wherein the bast fiber is a linen or ramie fiber.

46. A liquid crystal fiber according to Claim 44, wherein the liquid crystal fiber is a lyotropic liquid crystal fiber or a thermotropic liquid crystal fiber.

47. A lyotropic liquid crystal fiber according to Claim 46, wherein the lyotropic liquid crystal fiber is a para-aramid fiber.

48. A para-aramid fiber according to Claim 47, wherein the para-aramid fiber is a KEVLAR fiber.

49. A thermotropic liquid crystal fiber according to Claim 46, wherein the thermotropic liquid crystal fiber is a fully aromatic polyester fiber.

50. A fully aromatic polyester fiber according to Claim 49, wherein the fully aromatic polyester fiber is VECTRAN fiber.

51. A textile fabric comprising of a plurality of textile fibers at least one of said fibers having fibrils and cracks, or fibrils and kink bands, or cracks and kink bands, or fibrils, cracks and kinkbands.

52. A textile fabric according to Claim 51, wherein at least one of said plurality of fibers is a fiber selected from the group consisting of lyotropic liquid crystal fibers, para-aramid fibers, KEVLAR fibers, liquid crystal fibers, thermotropic liquid crystal fibers, fully aromatic polyester fibers, VECTRAN fibers, cellulosic vegetable fibers, bast fibers, ramie fibers, linen fibers.

53. A textile fabric comprising of a plurality of textile fibers at least one of said fibers having fibrils and enlarged nodes, or cracks and enlarged nodes, or fibrils, cracks and enlarged nodes, or fibrils and enlarged segregated fibrous tangles, or cracks and enlarged segregated fibrous tangles or fibrils, cracks and enlarged segregated fibrous tangles.

54. A textile fabric according to claim 53, wherein at least one of said plurality of fibers is a fiber selected from the group consisting of bast fibers, linen fibers, ramie fibers, thermotropic liquid crystal fibers, fully aromatic polyester fibers, and VECTRAN fibers.

55. An apparatus for modifying the texture and appearance of material which comprises:

(a) a closed hollow cylinder having an interior surface with curved walls;

(b) means for material entry and exit to said hollow cylinder;

(c) at least one gas jet directed away from the interior of the curved wall of said cylinder; and

(d) an air exhaust means for said hollow cylinder.

56. The apparatus according to Claim 56, wherein said gas jet is directed substantially tangential to the interior of the curved wall of said cylinder.

57. An apparatus as claimed in Claims 55 or 56, wherein gaseous fluid enters the hollow cylinder through said gas jet.

58. The apparatus according to Claims 55, 56 or 57, wherein said interior surface of said cylinder is disposed adjacent to a resilient means.

59. The apparatus according to Claims 55, 56 or 57, wherein said interior surface of said cylinder is disposed adjacent to an abrasive means.

60. The apparatus according to Claim 55, wherein at least one protrusion is secured to the said interior surface of said cylinder.

61. An apparatus as claimed in Claim 55, wherein heated gas enters the hollow cylinder through said gas jet.

62. An apparatus as claimed in Claim 61, wherein the heated gas is between the glass transition temperature and the melting point of the material.

63. An apparatus as claimed in Claim 55, wherein the material is a textile fabric.

64. An apparatus as claimed in Claim 55, wherein said gaseous fluid is steam.

65. An apparatus for modifying the texture and appearance of material which comprises:

(a) a plurality of closed hollow cylinders which intersect to have a closed common area;

(b) said hollow cylinders having interior surfaces with curved walls;

(c) means for material entry and exit to said hollow cylinders;

(d) at least one gas jet directed substantially tangential to the interior of the curved wall of at least one of said cylinders; and

(e) at least one gas exhaust means for said hollow cylinders.

66. The apparatus according to claim 65, wherein said interior surface of said cylinders is disposed adjacent to a resilient means.

67. The apparatus according to Claim 65, wherein said interior surface of said cylinders is disposed adjacent to an abrasive means.

68. The apparatus according to Claim 65, wherein at least one protrusion is secured to the said interior surfaces of said cylinders.

69. An apparatus as claimed in Claim 65, wherein heated gas enters the hollow cylinders through said gas jet.

70. An apparatus as claimed in Claim 69, wherein the heated gas is between 150° Fahrenheit to 350° Fahrenheit.

71. An apparatus as claimed in Claim 65, wherein the material is a textile fabric.

72. An apparatus as claimed in Claim 65, wherein vaporized water enters the hollow cylinders through said gas jet.

73. A method for modifying the texture and appearance of material comprising the steps of:

(a) delivering a material to a hollow cylinder having an inner surface;

(b) creating a high velocity vortex in the cylinder by means of at least one gas jet directed substantially tangential to the inner surface of the cylinder which thereby causes the material to rotate with the cylinder; and

(c) removing the material from the cylinder.

74. A method for modifying the texture and appearance of materials comprising the steps of:

(a) delivered a material to a plurality of hollow cylinders having interconnecting passages;

(b) creating a plurality of interacting vortices in the cylinders by means of at least one gas jet directed substantially tangential to the inner surface of at least one of the cylinders which thereby causes the material to rotate between the cylinders; and

(c) removing the material from the cylinders.

75. A method as claimed in Claims 73 or 74, wherein the material is a textile fabric.

76. A method as claimed in Claims 73, 74 or 75, wherein particles are delivered to the cylinder with the material.

77. A method as claimed in Claim 76, wherein the particles are selected from the group consisting of sand, metal shot, wire portions, rubber, plastics and wood.

78. A method as claimed in Claims 73 or 74, wherein the gas jet is heated.

79. A method as claimed in Claims 73 or 74, wherein the material is chemically treated.

80. A method as claimed in Claim 73, wherein the material is wetted by a liquid.

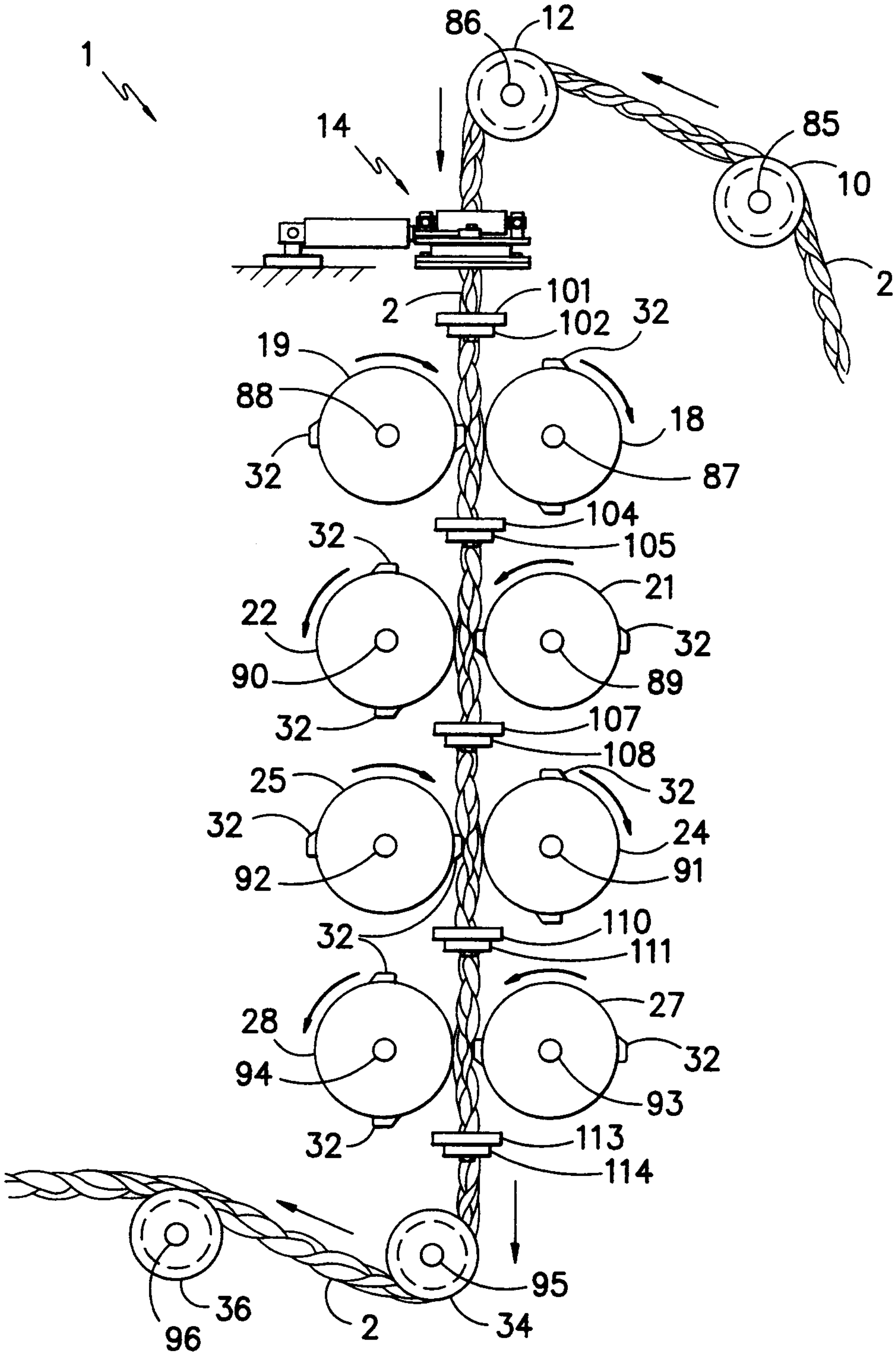

1
86
12
14
85
10
2
2
101
102
32
19
88
18
87
32
32
104
105
32
21
22
32
90
89
32
107
108
25
32
32
24
92
91
32
110
111
27
28
32
94
93
32
113
114
95
36
34
96
2

FIG. —1—

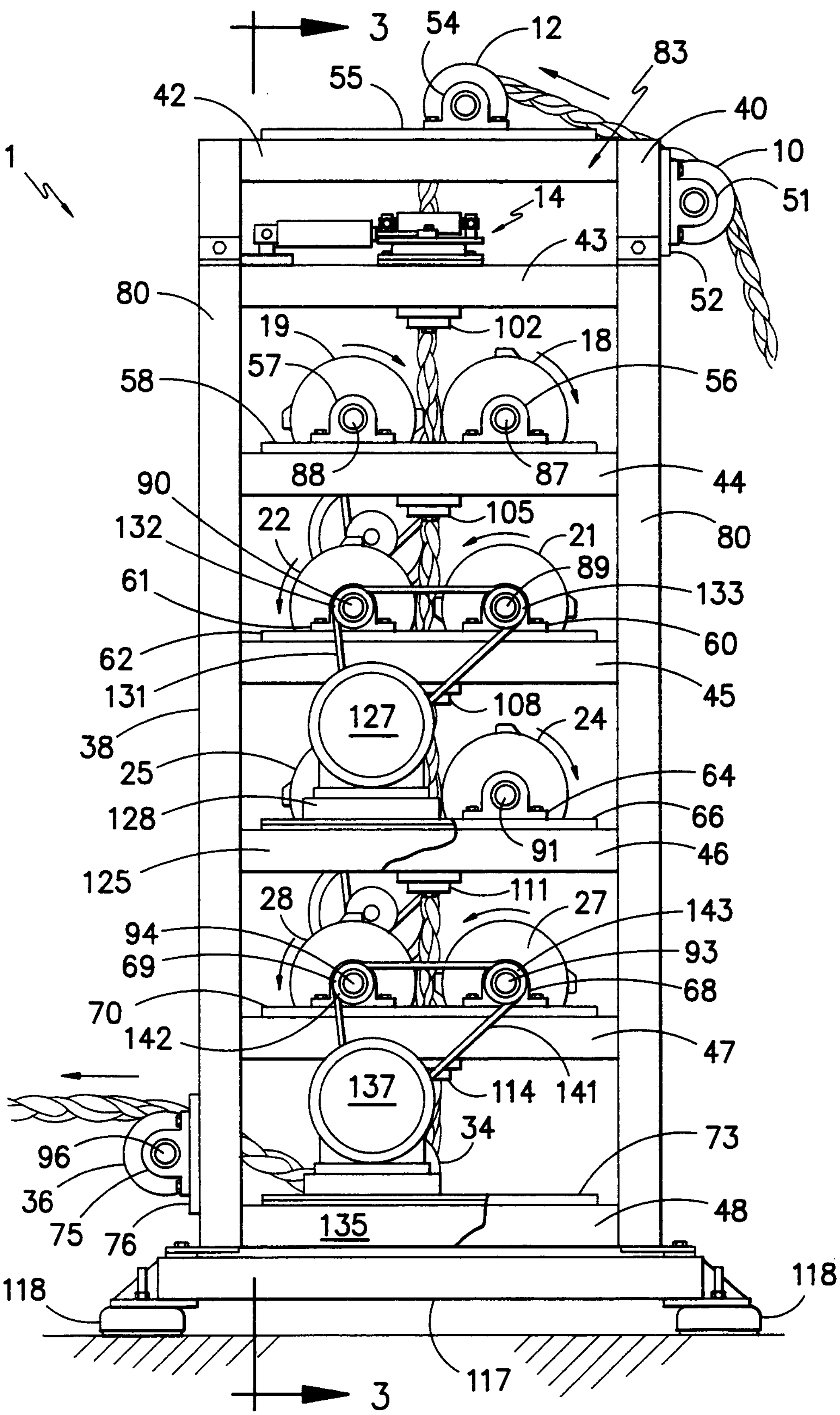
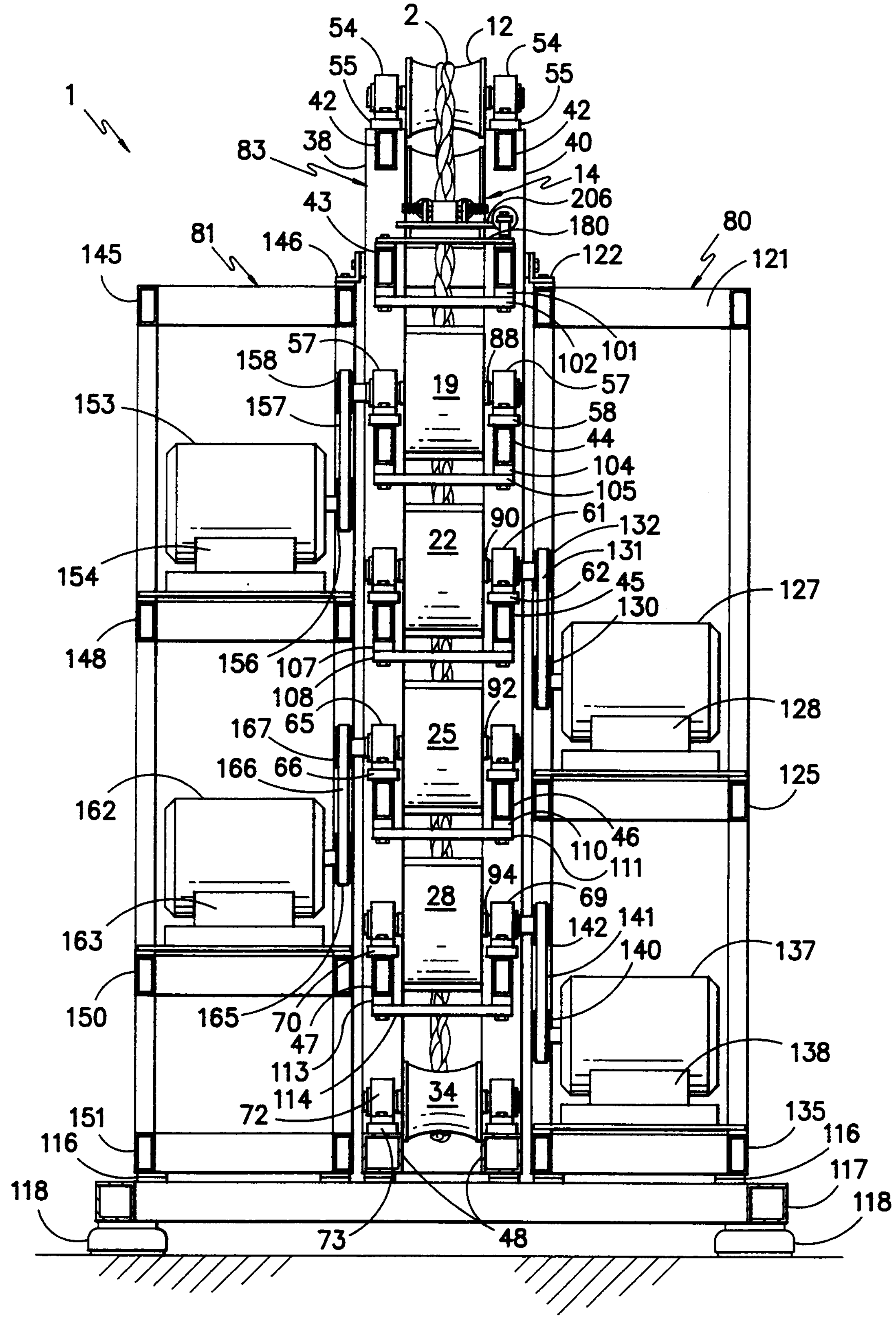

3
54
12
83
55
42
40
10
1
51
14
43
80
52
102
19
18
57
58
56
88
87
44
90
105
22
132
21
80
89
61
133
62
60
131
45
108
127
24
38
25
64
128
66
46
91
125
111
28
27
143
94
93
69
68
70
142
47
137
114
141
34
96
73
36
75
76
135
48
118
118
117
3

FIG. -2-



1
2
12
54
55
42
38
83
40
14
206
180
43
146
81
145
80
121
122
101
102
88
57
19
158
157
153
58
44
104
105
22
90
61
132
131
62
45
130
127
154
148
156
107
108
92
25
65
167
66
166
128
125
162
46
110
111
28
94
69
142
141
140
137
163
150
165
70
47
113
114
138
34
72
151
116
135
117
118
73
48

FIG. —3—

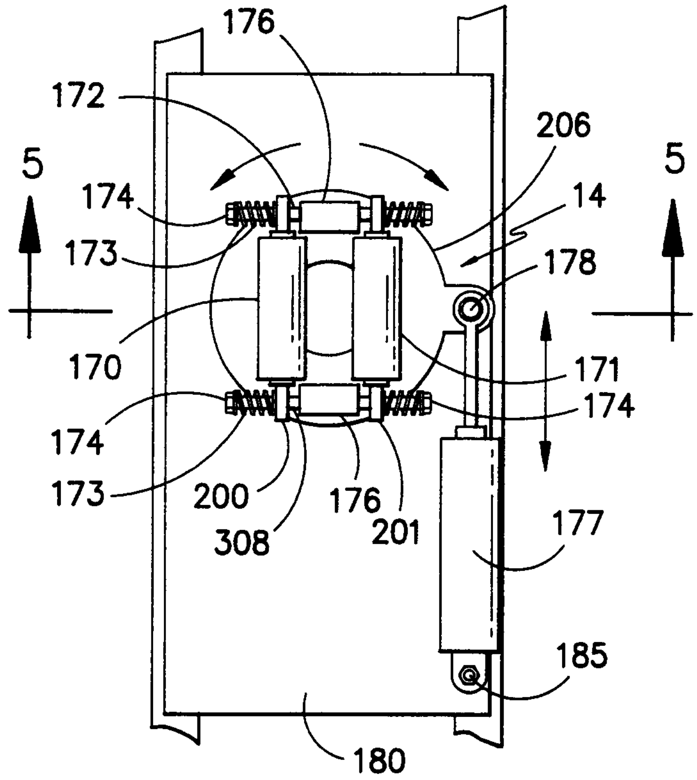


FIG. -4-

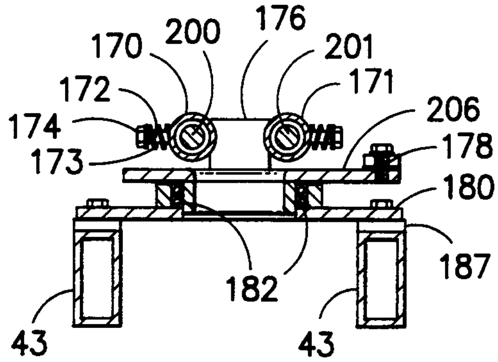


FIG. -5-

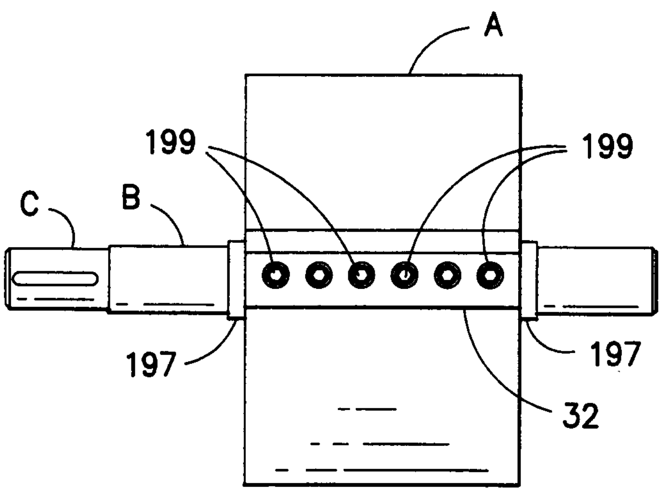


FIG. -6-

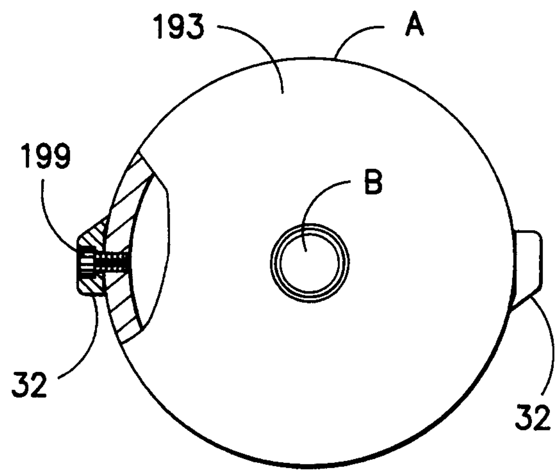


FIG. -7-

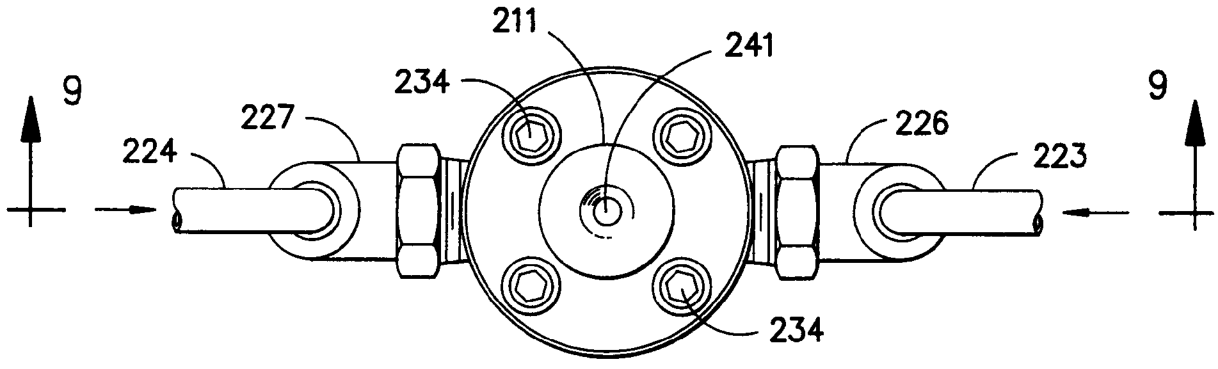

211
241
234
9
227
226
9
224
223
234

FIG. -8-

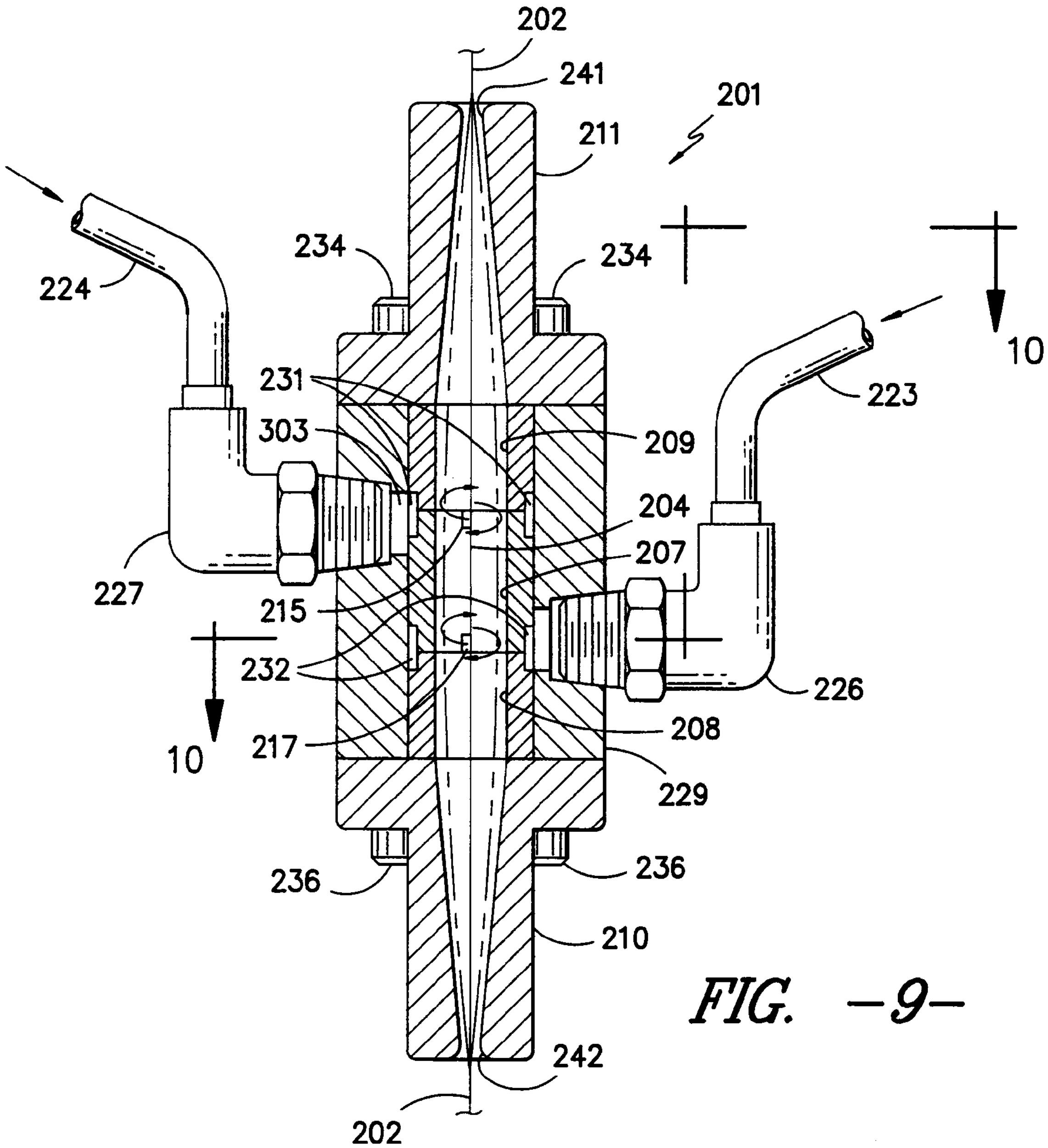

202
241
201
211
234
234
224
10
231
223
303
209
204
207
227
215
232
226
208
10
217
229
236
236
210
242
202

FIG. -9-

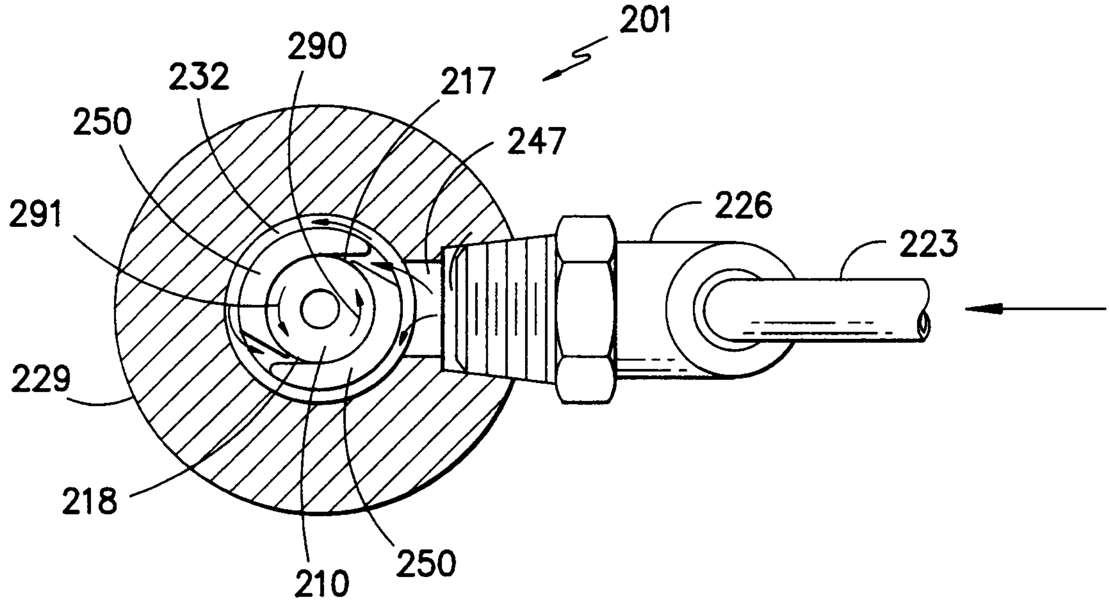

201
290
232
217
250
247
226
223
291
229
218
210
250

FIG. –10–

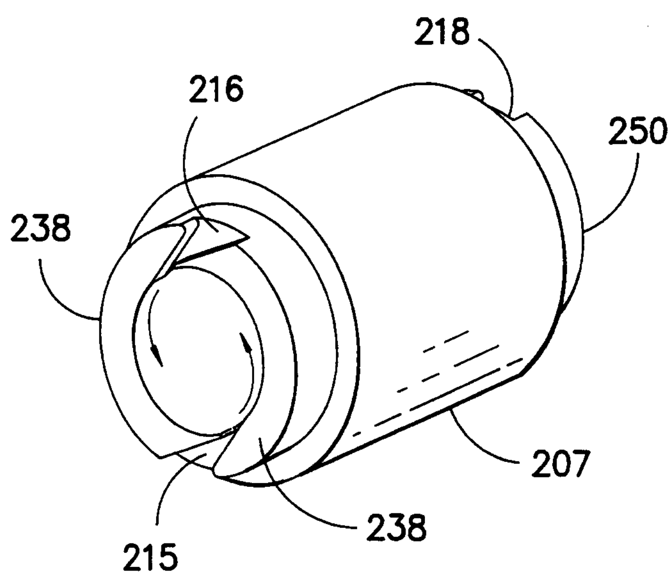

218
216
250
238
207
238
215

FIG. –11–

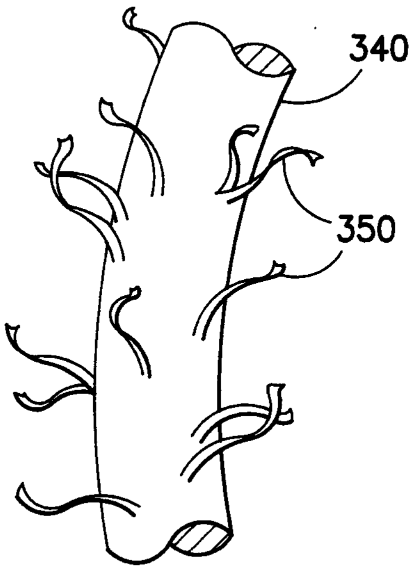


FIG. -12-

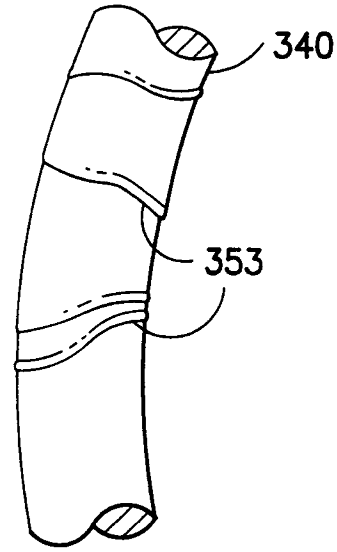


FIG. -13-

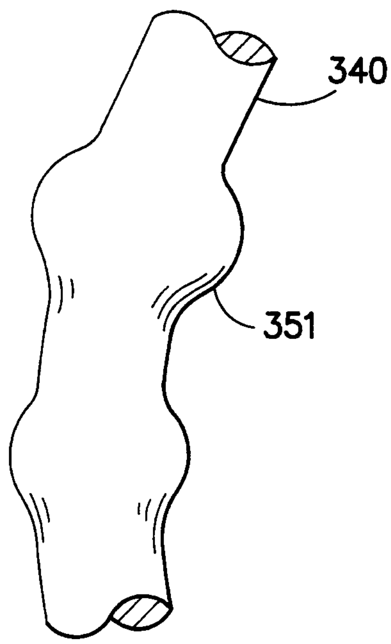


FIG. -14-

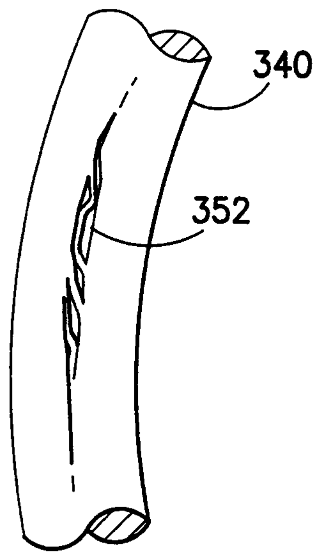


FIG. -15-

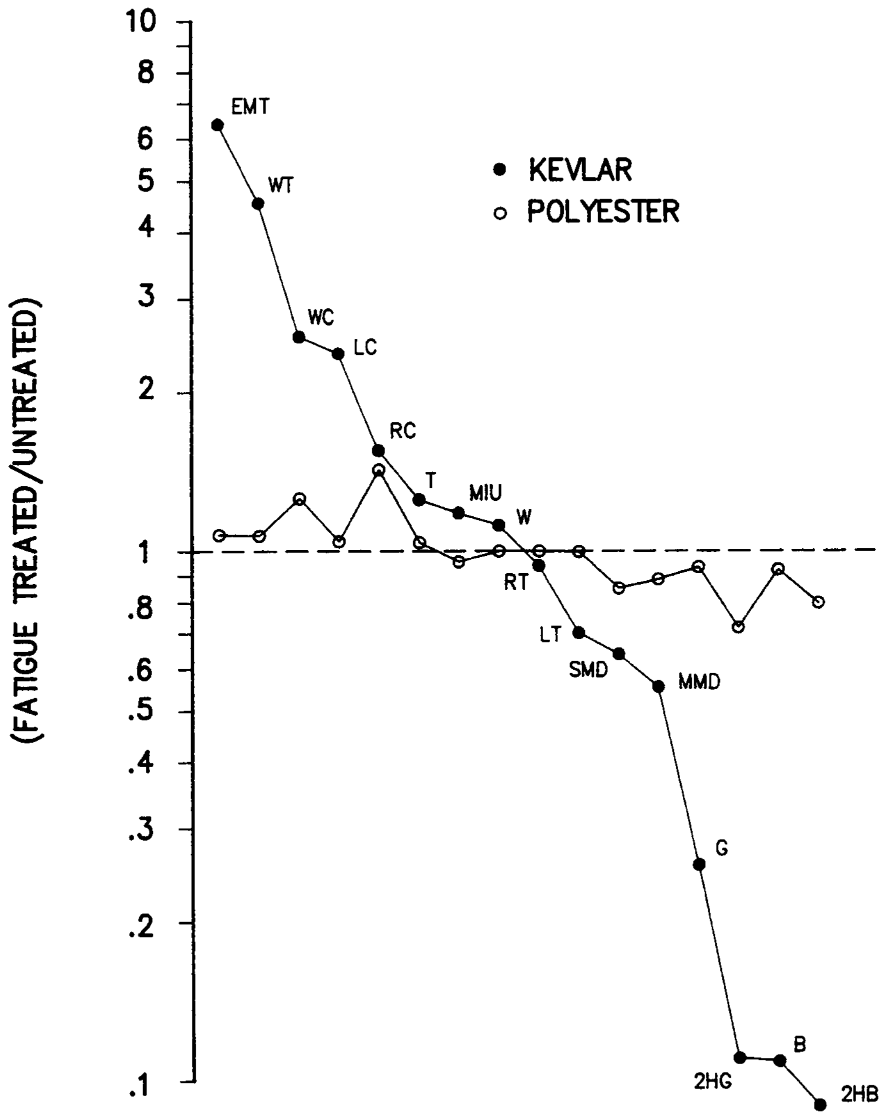

10
8
6
5
4
3
2
1
.8
.6
.5
.4
.3
.2
.1
(FATIGUE TREATED/UNTREATED)
KEVLAR
POLYESTER
EMT
WT
WC
LC
RC
T
MIU
W
RT
LT
SMD
MMD
G
B
2HG
2HB

FIG. –16–

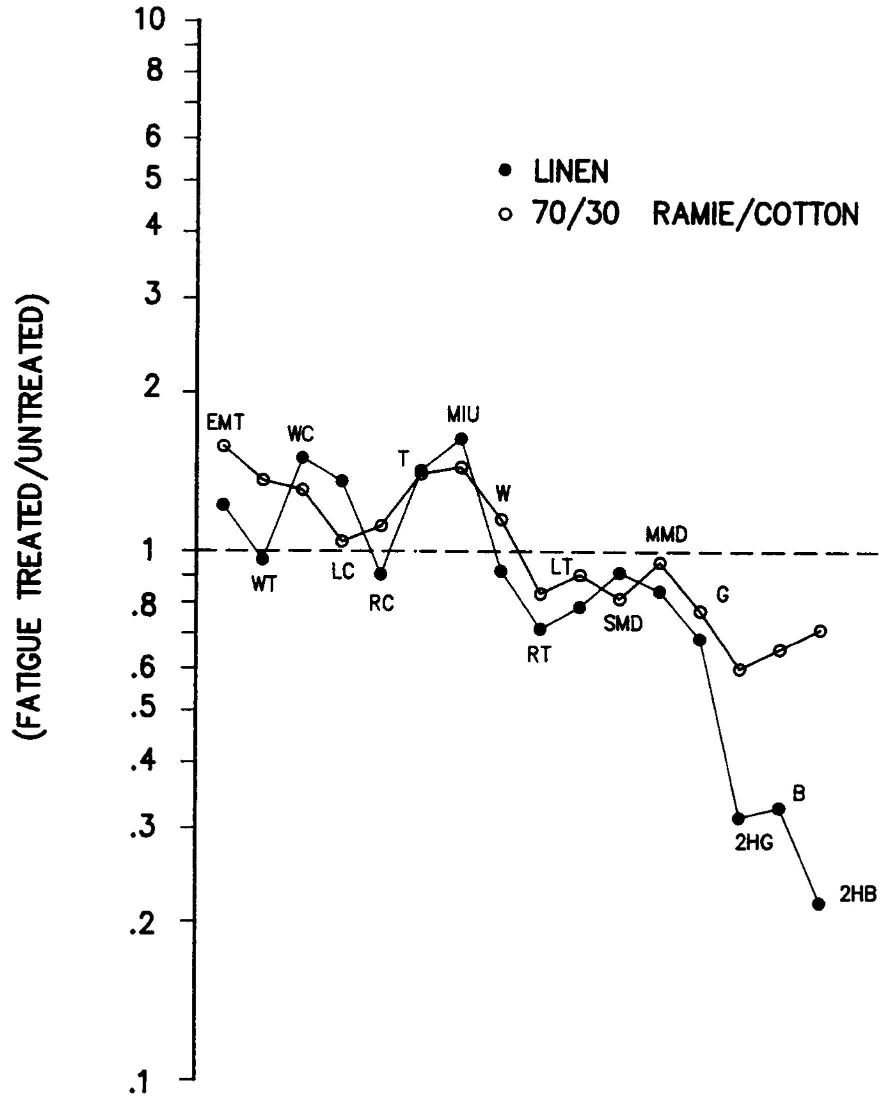

10
8
6
5
4
3
2
1
.8
.6
.5
.4
.3
.2
.1
(FATIGUE TREATED/UNTREATED)
• LINEN
○ 70/30 RAMIE/COTTON
EMT
WT
WC
LC
RC
T
MIU
W
RT
LT
SMD
MMD
G
2HG
B
2HB

FIG. –17–

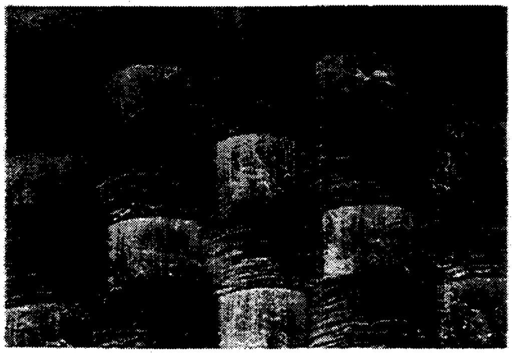


FIG. -18-


FIG. -21-

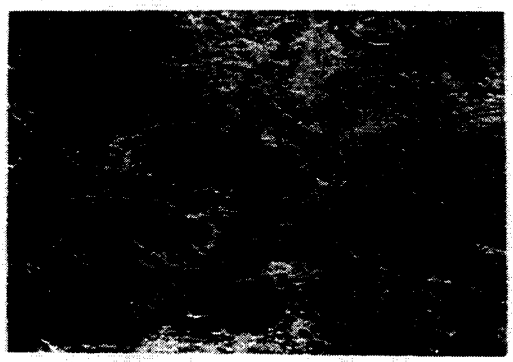


FIG. -19-


FIG. -22-

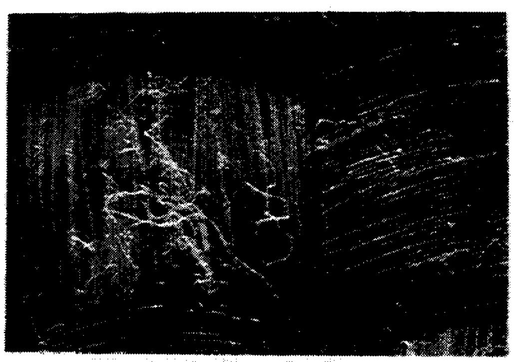


FIG. -20-

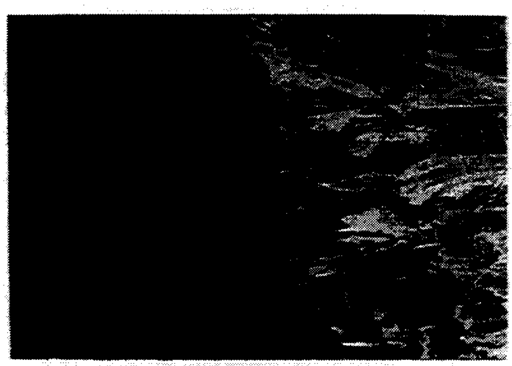


FIG. -23-

FIG. -24-

FIG. -25-

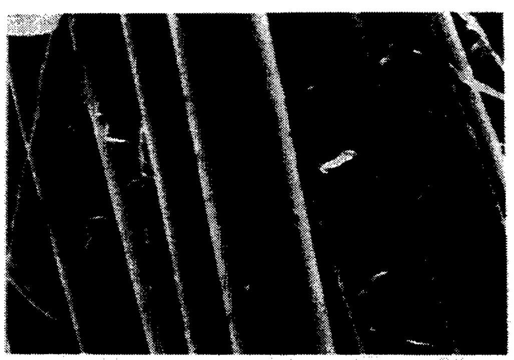


FIG. -26-

FIG. -27-

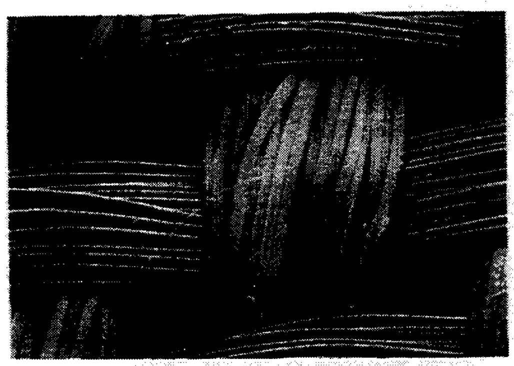


FIG. -28-

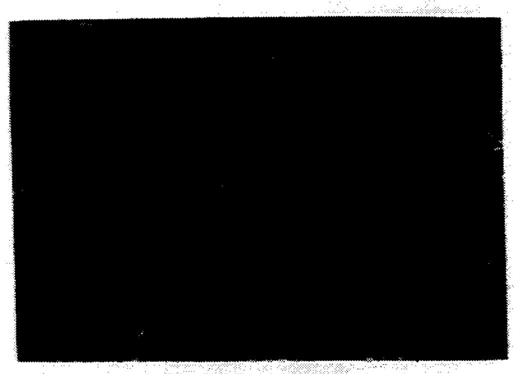


FIG. -29-

FIG. -30-

FIG. -33-

FIG. -31-

FIG. -34-

FIG. -32-

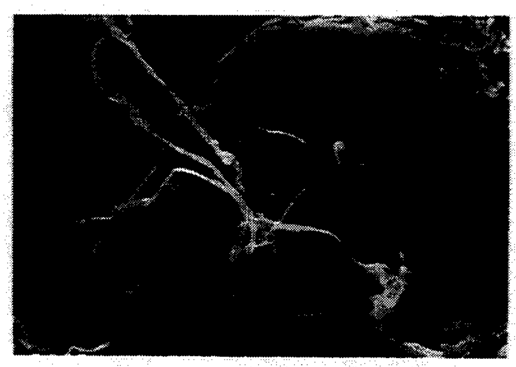


FIG. -35-

FIG. -36-

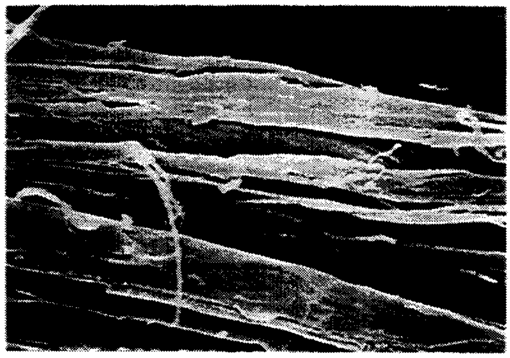


FIG. -39-

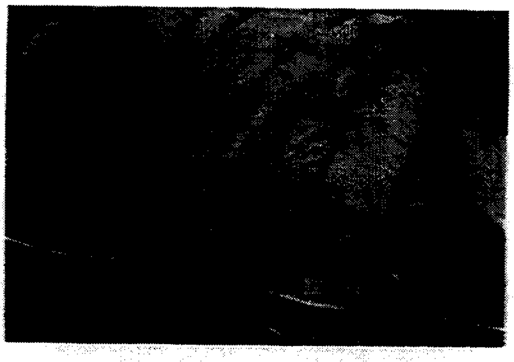


FIG. -37-

FIG. -40-

FIG. -38-

FIG. -41-

FIG. –42–

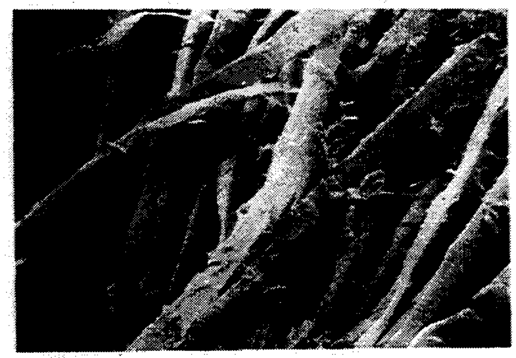


FIG. –45–

FIG. –43–

FIG. –46–

FIG. –44–

FIG. –47–

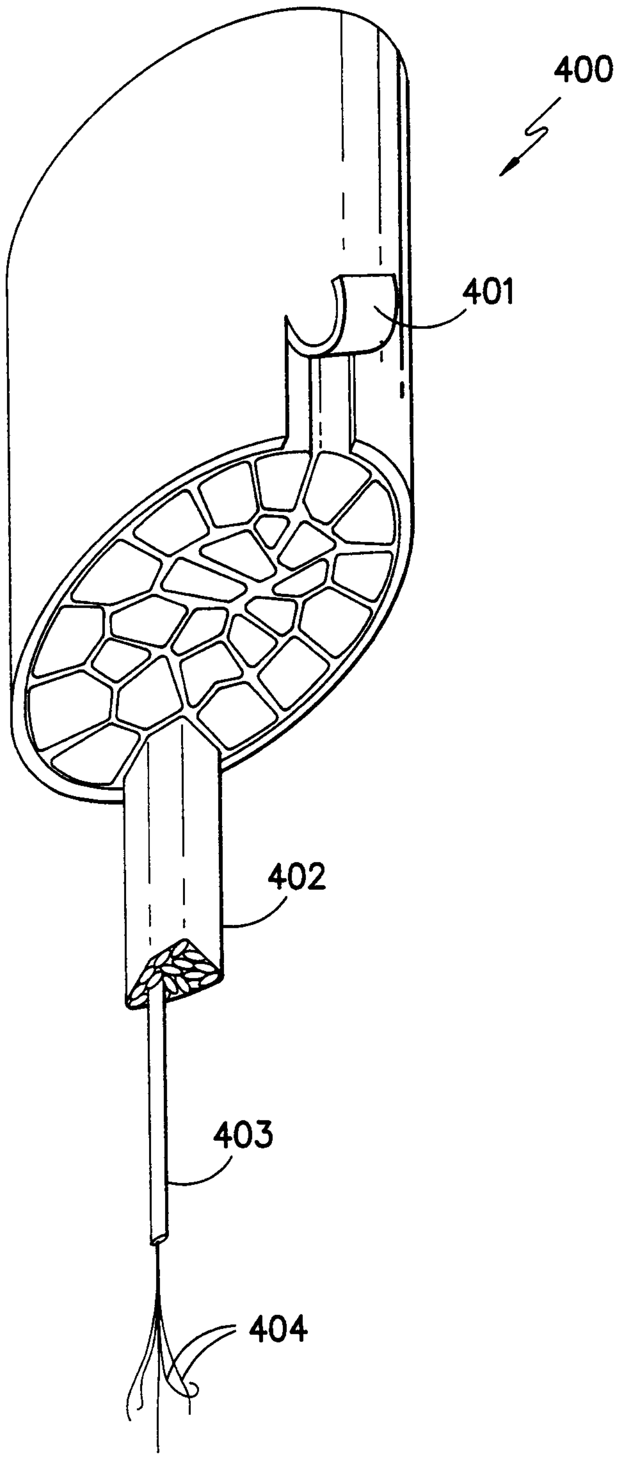


FIG. –48–

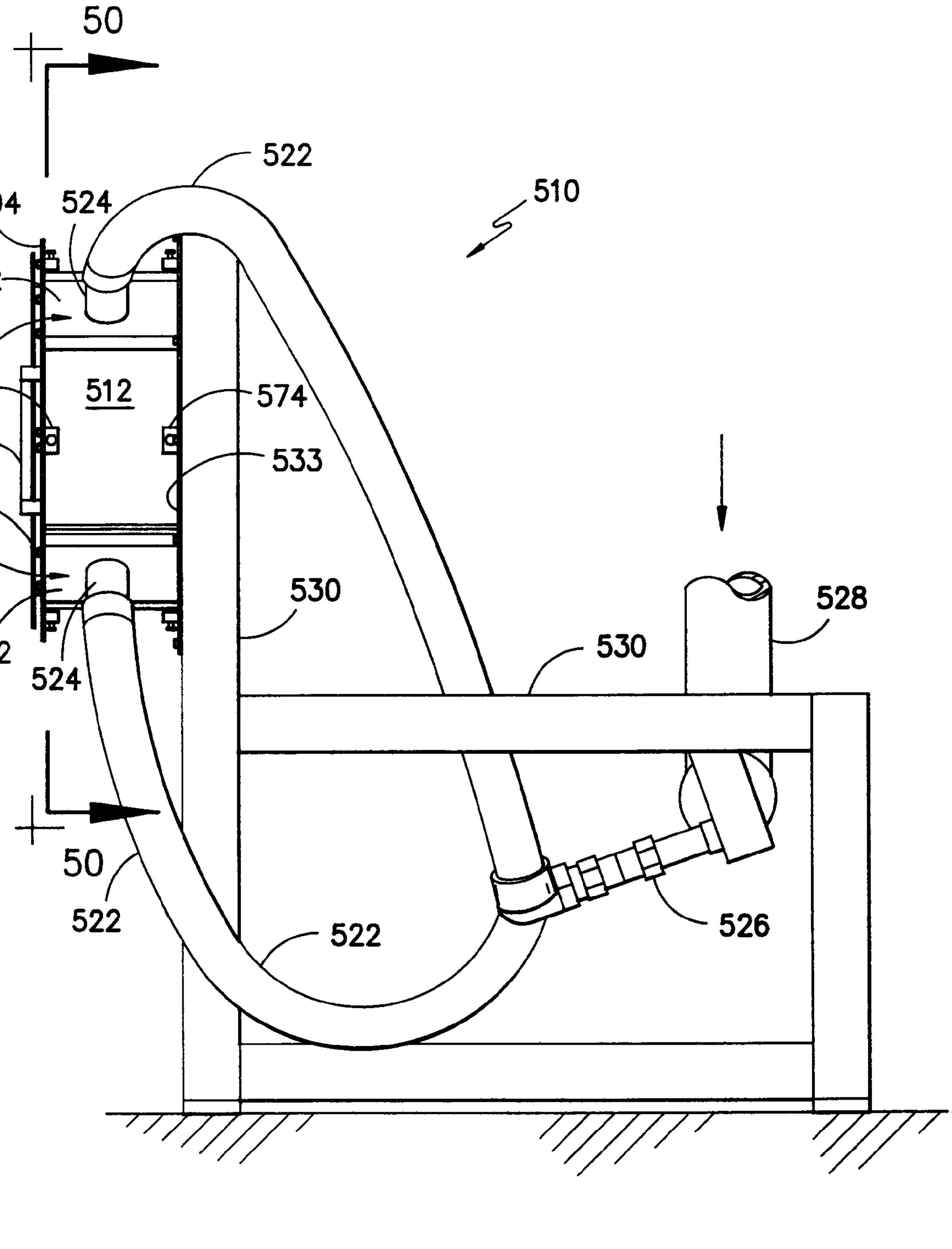

50
522
510
594
524
532
520
512
574
574
596
533
590
520
530
528
530
532
524
50
522
522
526

FIG. —49—

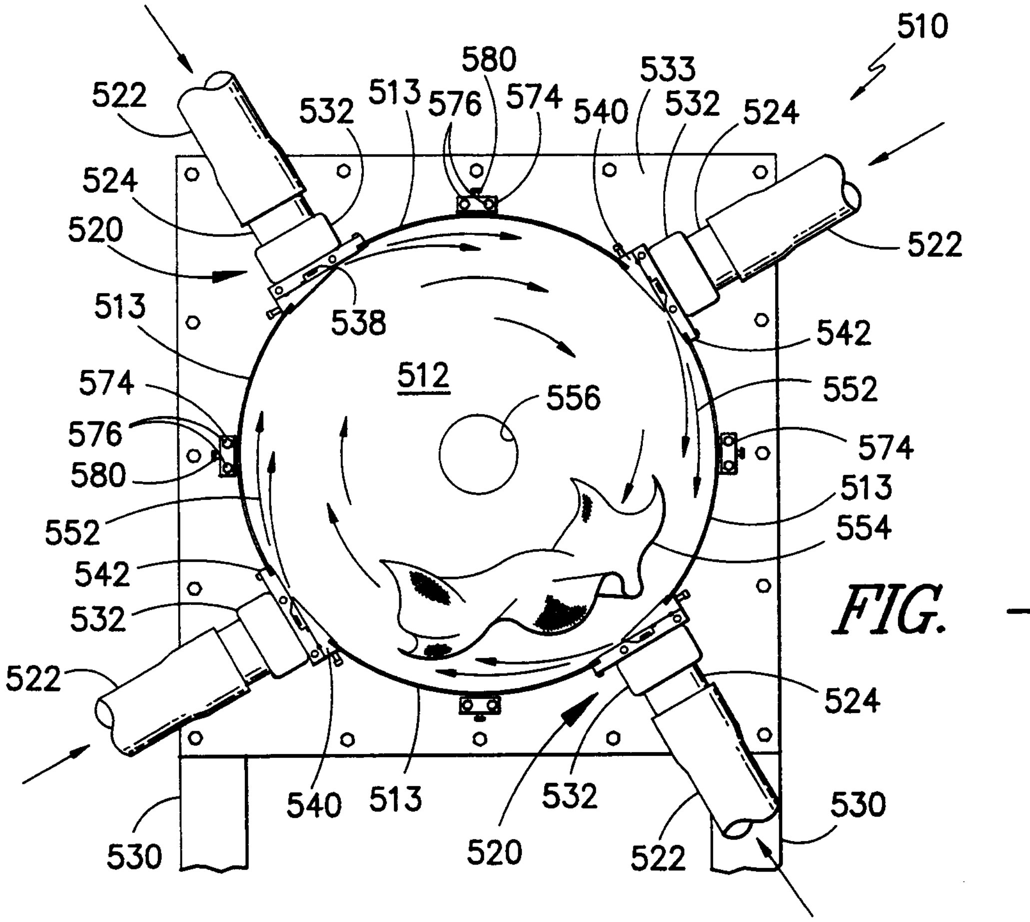

510
580
533
522
532
513
576
574
540
532
524
524
522
520
538
542
513
512
556
552
574
576
574
580
513
552
554
542
532
524
522
530
540
513
532
530
520
522

FIG. -50-

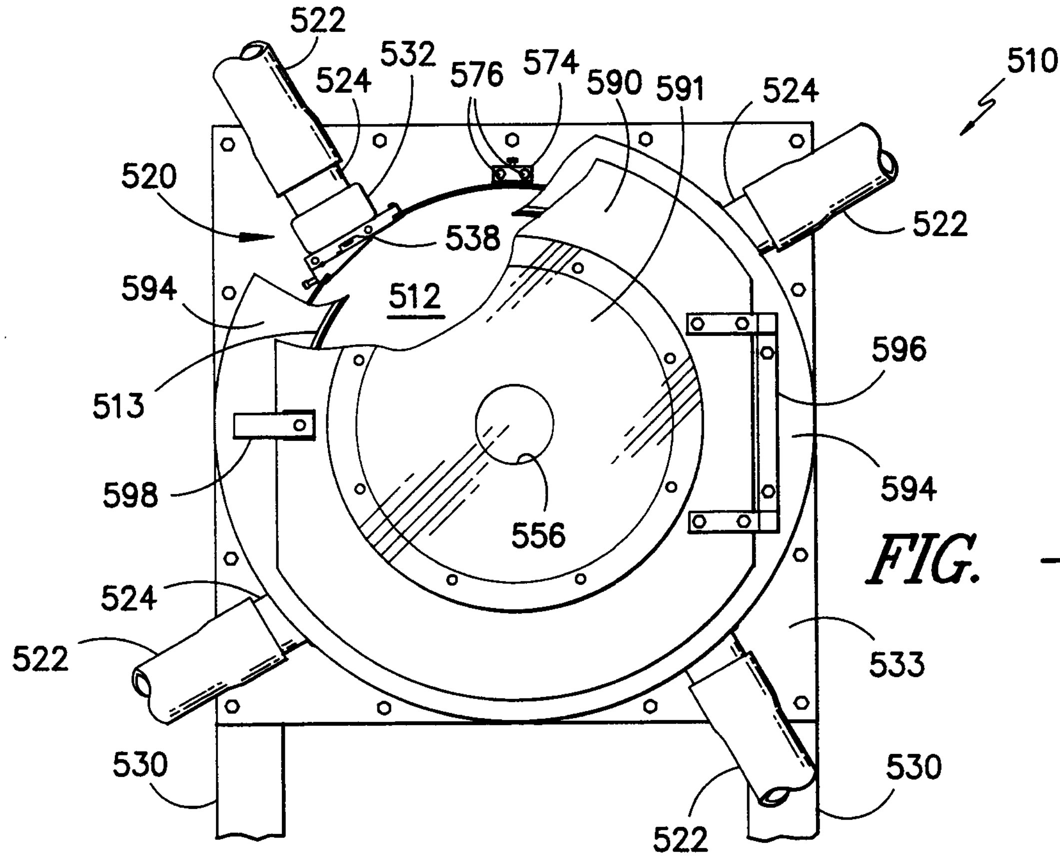

522
532
576
574
590
591
524
510
524
520
522
538
594
512
513
596
598
594
556
524
533
522
530
530
522

FIG. -51-

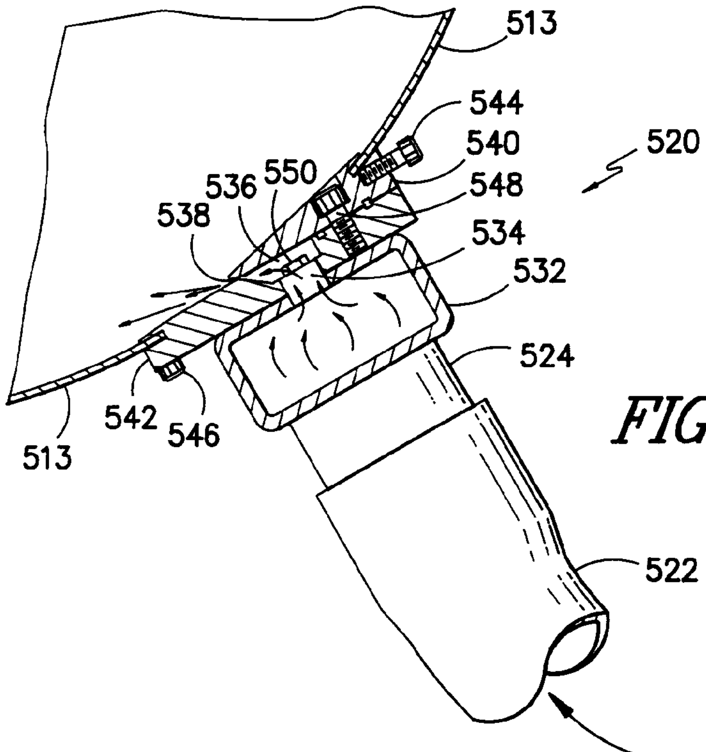

513
544
540
520
550
548
536
538
534
532
524
542
546
513
522

FIG. -52-

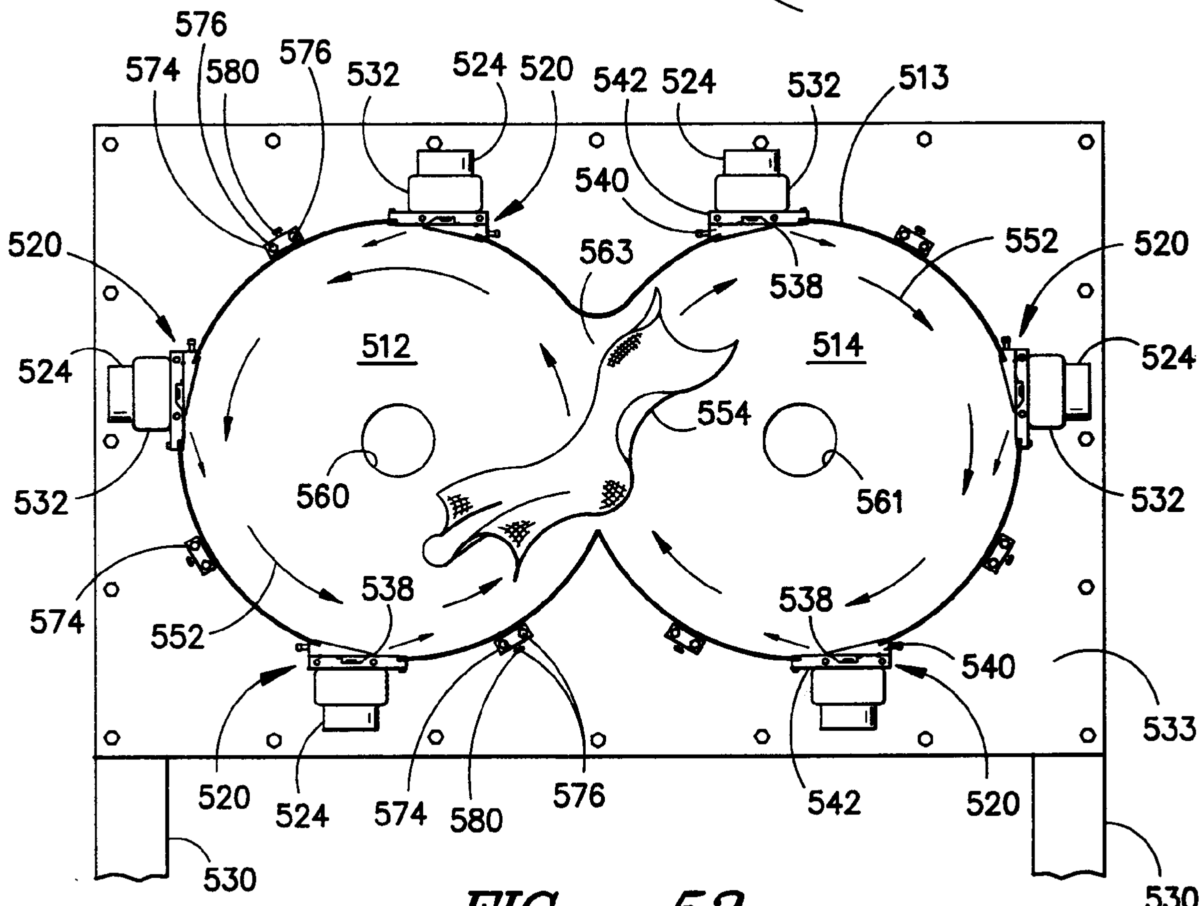

576
574
580
576
532
524
520
542
524
532
513
540
520
563
552
520
538
512
514
524
524
554
560
561
532
532
574
538
538
552
540
533
520
524
574
580
576
542
520
530
530

FIG. -53-

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 91 30 9427

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X	DE-A-3 332 338 (MENSCHNER) * the whole document *	1-6	D06C15/14 D06C19/00 D02J3/02
A	DE-A-3 219 086 (BABCOCK)		
A	EP-A-0 300 611 (MILLIKEN)		
A	EP-A-0 010 546 (TEIJIN)		
A	US-A-4 055 003 (JOHNSON & JOHNSON)		
A	US-A-4 112 558 (CHRISTIAN)		
A	FR-A-2 157 670 (HÜTER)		
A	GB-A-2 113 260 (HOLLANDSE SIGNAALAPPARATEN)		

TECHNICAL FIELDS SEARCHED (Int. Cl.5)

D06C
D02J

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	20 JANUARY 1992	PETIT J.P.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P0401)