## Oct. 21, 1969

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Filed Dec. 14, 1967

3 Sheets-Sheet 1



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Fig. 8

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Fig. 9



Fig. 10



Fig. 11

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3,473,576 WEAVING POLYESTER FIBER FABRICS John S. Amneus, Cincinnati, Ohio, assignor to The Procter & Gamble Company, Cincinnati, Ohio, a corporation of Ohio Filed Dec. 14, 1967, Ser. No. 690,497 Int. Cl. D03d 15/00, 15/02; B01d 39/10 U.S. Cl. 139-420

7 Claims

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#### ABSTRACT OF THE DISCLOSURE

A process for the production of a dimensionally heat stable monofilament polyester fiber fabric characterized by uniform knuckle heights in conjunction with mini- 15 mum free area. Uniform knuckle heights in conjunction with minimum free area are achieved in the monofilament polyester fiber fabric of this invention by selecting warp and woof polyester monofilaments of substantially equal diameter but different heat shrinkage potential, weaving 20 fabric at calculated warp spacing and caliper dimensions, and shrinking the so woven fabric by heat treatment while maintaining warp tension.

#### BACKGROUND OF THE INVENTION

This invention relates to improvements in the weaving and treating of polyester fiber fabrics and to the provision of a dimensionally heat stable monofilament polyester 30 this invention are applicable in other areas of monofilafiber fabric. More particularly, the invention provides a dimensionally heat stable monofilament polyester fiber fabric which is characterized by equal knuckle heights in conjunction with minimum free area.

Specifically, the invention in one of its more important 35 embodiments consists of an improved monofilament polyester fiber fabric of the type used for transporting a moist web through the forming, pressing and drying sections of a papermaking machine, which monofilament polyester fiber fabric is woven and thereafter shrunk by 40 heat treatment to result in a dimensionally heat stable fabric having equal knuckle heights in conjunction with a free or interstitial area of about 14% to about 20% of the fabric surface area.

In referring to monofilament polyester fiber fabrics 45 herein, applicant intends references to fabrics wherein both the warp and the woof threads of the fabric are monofilament polyester fibers, for example, the monofilament polyamide fibers, vinyl fibers, acrylic fibers and polyester fibers sold under the tradenames of "nylon," "Saran," "Orlon," "Dacron" and "Treviera." While both 50the warp and woof threads in woven fabrics can be made up of a multiplicity of fibers, the present invention, as stated above, is concerned with warp and woof threads composed of one single extruded fiber of specified size, 55 i.e., monofilaments. The warp and woof polyester monofilament fibers with which the present invention is particularly concerned have a diameter of about 0.008 inch to about 0.020 inch, although the principles of the invention can be applied to monofilament polyester fibers of 60 any practical dimension. Further, the present monofilament polyester fiber fabrics are all of "plain" or tabby weave, although certain of the disclosed benefits can in some measure be obtained in fabrics of other construction, for example, in twilled and semi-twilled fabrics. The 65 term, knuckle, refers to the cross-over points of the warp and woof threads making up the monofilament polyester fabric, and it is noted that the instant plain weave monofilament polyester fabrics are preferentially those wherein the warp and woof threads have substantially equal diam- 70 eters. Fabrics woven and heat treated according to the present process are characterized by knuckles of equal

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height, i.e., knuckles whose distal surfaces lie in the same plane.

In one important embodiment, the monofilament polyester fiber fabrics of this invention were developed to reduce or eliminate foraminous carrier problems in forming, pressing and drying moist webs in Fourdrinier and other papermaking operations as well as in the manufacture of non-woven webs. Persons skilled in the papermaking and non-woven web manufacturing arts will recognize that several transfers, from one endless carrier belt to another, of a partially formed dried fibrous web with little mechanical strength occur in such operations. These transfers, assuming the initial formation of a desirable fibrous web structure, are of importance in that they can only disrupt bonds, entanglements and other mechanical and chemical features which contribute to a desirable final structure in the fibrous web. To avoid the foregoing transfer problems and to satisfy other web formation criteria, for example drainage and surface appearance, an ideal monofilament polyester fiber fabric for use in non-woven web manufacturing, and, particularly, in papermaking operations, should possess characteristics which allow the fabric to adhere sufficiently to a web structure at its various stages of formation, press-25 ing and drying to act as a carrier. At the same time, the monofilament polyester fiber fabric should not interfere with the web structure or impart undesirable characteristics to this structure during transfers.

Although the weaving and fabric treatment criteria of ment polyester fiber fabric use, the instant features will be most readily understood in respect to the use of such fabrics as carriers in web formation operations. In these operations, for example in the operation of a paper machine according to the teaching of U.S. 3,301,746, improved web transferability and drying surface contact is desired, and the monofilament polyester fiber fabrics used should not contribute factors to the final paper product other than those desired by the papermaker and designed into the paper product.

In particular, it has been discovered that the use of monofilament polyester fiber fabrics of unequal knuckle height in the press and drying sections of a papermaking machine introduces problems in the transfer of a moist paper web to a drying surface by reducing dryer surface contact with the moist paper web. Although it might be expected that the weaving of a monofilament polyester fiber fabric having uniform kunckle heights and minimum free area would be relatively simple, such did not prove the case because of the heat applied to such fabrics in web formation apparatus and in the final treatment of fabrics in web formation apparatus and in the final treatment of fabrics by weavers. It was found that monofilament polyester fiber fabrics initially woven with uniform knuckle heights would distort or shrink when heated, so that the knuckle heights became uneven. Also, the specification of minimum free area or "tight-weave" fabrics of the type considered desirable for web formation carrier fabrics accentuated the problems of obtaining uniform knuckle heights in a monofilament polyester fiber fabric which was dimensionally stable under the temperatures encountered in paper and non-woven web drying operations. Accordingly, it was desired to develop a weaving process whereby a monofilament polyester fiber fabric could be woven to exhibit in combination the characteristics of dimensional heat stability, even knuckle height and minimum free area.

#### SUMMARY OF THE INVENTION

Inasmuch as a means of weaving a dimensionally heat stable monofilament polyester fiber characterized by equal knuckle heights and minimum free area was de-

sired for the production of fabrics particularly suitable for use as carriers in web formation operations, the monofilament fiber fabrics and processes for their weaving and shrinkage by heat treatment which comprises this invention were developed. In general, the present monofilament polyester fiber fabric is prepared by selecting polyester warp monofilaments having a relatively high heat induced shrinkage potential and further selecting an initial warp monofilament spacing in the loom according to a mathematical equation more fully discussed hereinbelow. After selecting and spacing the warp monofilaments, polyester woof monofilaments are selected which have a relatively low heat induced shrinkage potential, and these woof monofilaments are woven and beaten in the weaving process into a plain weave fabric having an initial caliper calculated according to yet another mathematical equation discussed below. After initial weaving, the fabric knuckles are brought to equal heights, and the minimum free area of the present monofilament polyester fabric is set by a heat shrinkage treatment. The heat shrinkage treatment takes advantage of the aforementioned shrinkage characteristics of the warp and the woof polyester monofilaments. The heat shrinkage treatment comprises subjecting the initially woven fabric to a series of heat applications while it 25 is stretched and secured at its ends in the lengthwise or warp direction, but is free to shrink in the woof direction. The heat shrinkage treatment is conveniently applied to the initially woven fabric while the fabric is mounted as an endless belt on a finishing table such 30 knuckle cross-over points, prior to heat shrinking, in a as those conventionally used in finishing metal Fourdrinier wires. A conventional wire finishing table consists of two adjustable rolls for supporting, tensioning and driving the wire or fabric to be finished as an endless belt. The heat shrinkage can be induced conveni-35 ently by an infrared source mounted as a bank above and across the initially woven fabric. The infrared source heats areas of the initially woven fabric as is slowly revolves on the rolls of the wire finishing table. Multiple passes are used to avoid sudden shrinkage which  $_{40}$ induces fabric wrinkles and to achieve final dimensional heat stability. In this manner a monofilament fabric having knuckles of equal height and a free area of about 14% to about 20% is produced.

Contrary to expectation, a weaving procedure where-45 in polyester warp and woof monofilaments are merely woven as tightly as possible to insure a minimum free area will not result in a monofilament polyester fiber fabric with equal knuckle heights after heat treating or use in web drying systems. Polyester fibers in general 50 exhibit heat shrinkage, and if such a tight weaving procedure involving initial minimum spacing in both the polyester warp and woof monofilaments is attempted, the resulting heat treated and heat stabilized monofilament polyester fiber fabric will exhibit uneven knuckle heights. As discussed below, a greater or lesser warp monofilament spacing than used in the presently disclosed process will also fail to produce equal knuckle heights. Applicant has discovered that the achievement of minimum free areas and equal knuckle heights in a dimensionally heat stable monofilament polyester fiber fabric is only achieved by taking into account the heat induced shrinkage of the polyester monofilaments in the fabric in a weaving process wherein the selection, initial spacing and handling of the warp and woof monofilaments is bal-65anced to achieve the desired result. It is, accordingly, the principal object of this invention to improve the weaving of monofilament polyester fiber fabrics and to overcome other associated problems and disadvantages.

Another object of this invention is to provide dimen- 70 sionally heat stable monofilament polyester fiber fabrics for use in fibrous web carrying and other fabric-using operations, which monofilament polyester fiber fabrics are characterized to equal knuckle heights and minimum free areas.

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It is a further object of this invention to provide a process for the production of dimensionally heat stable monofilament polyester fiber fabrics, which process sets criteria for weaving and heat treating operations achieving equal knuckle heights and minimum free areas.

It is yet another object of this invention to provide minimum free area monofilament polyester fiber fabrics for use as carrier fabrics in the forming, press and drying sections of paper machines, which fabrics have knuckles of equal height and contribute materially to the avoidance of transfer and contact problems in papermaking and web formation operations.

### BRIEF DESCRIPTION OF THE DRAWINGS

15Other objects and advantages of this invention will become apparent as the description thereof proceeds in accordance with, and as illustrated by, the drawings, wherein the appearance, prior to heat shrinkage, of monofilament polyester fibers and fabrics initially woven 20 according to the process of this invention is illustrated in FIGURES 1, 2, 4 and 5. FIGURES 3, 6 and 7 illustrate dimensionally heat stable monofilament polyester fiber fabrics, or enlarged sections thereof, produced by heat treating the initially woven fabrics illustrated in FIG-URES 1, 2, 4 and 5. FIGURES 8, 9, 10 and 11 illustrate unequal knuckle heights resulting from both greater and lesser warp spacings than those disclosed below for use in the practice of the present weaving process.

FIGURE 1 is an enlarged cross-sectional view of monofilament polyester fiber fabric woven according to the present process with a woof fiber crimp, or set angle α, of 30°.

FIGURE 2 is an enlarged cross-sectional view of knuckle cross-over points, prior to heat shrinking, in a monofilament polyester fiber fabric woven according to the present process with a woof fiber set angle of 0°

FIGURE 3 is an enlarged cross-sectional view of knuckle cross-over points in a monofilament polyester fiber fabric woven as shown in FIGURE 1 and then heat treated according to the present process; the knuckles 11 of equal height achieved are illustrated.

FIGURE 4 is an enlarged plan view of the present monofilament polyester fiber fabric after weaving and prior to heat treating.

FIGURE 5 is an enlarged cross-sectional view corresponding to FIGURE 1 and is taken along line 5-5 of FIGURE 4 to illustrate the unequal knuckle heights in the present fabric prior to heat treatment.

FIGURE 6 is an enlarged plan view of a monofilament polyester fiber fabric woven and heat treated according to the process of this invention.

FIGURE 7 is an enlarged cross-sectional view corresponding to FIGURE 3 and is taken along line 7-7 of 55 FIGURE 6 to illustrate the equal knuckle heights characteristic of monofilament polyester fiber fabrics woven and heat treated according to the present process.

FIGURE 8 is an enlarged cross-sectional view of knuckle cross-over points, prior to heat shrinking, in a 60 monofilament polyester fiber fabric woven with a warp monofilament fiber spacing 20% less than that of the present process.

FIGURE 9 is an enlarged cross-sectional view of the knuckle cross-over points illustrated in FIGURE 8 after heat shrinking; the unequal height of the knuckles is shown.

FIGURE 10 is an enlarged cross-sectional view of knuckle cross-over points, prior to heat shrinking, in a monofilament polyester fiber fabric woven with a warp monofilament fiber spacing 20% greater than that of the present process.

FIGURE 11 is an enlarged cross-sectional view of the knuckle cross-over points illustrated in FIGURE 10 after heat shrinking; the unequal height of the knuckles is 75 shown.

#### DESCRIPTION OF THE PREFERRED EMBODIMENTS

In describing the initially calculated warp spacing X and fabric caliper Y, which together with warp and woof monofilament polyester fiber selection and heat treat-5 ment combine to achieve the production of a monofilament polyester fiber fabric characterized by equal knuckle heights together with minimum free area of about 14% to about 20%, FIGURES 1, 2, 4 and 5 are referred to to illustrate the appearance of the present monofilament 10 polyester fiber fabrics after weaving but prior to heat treatment. It is noted that FIGURE 1 illustrates that, prior to heat shrinking, the knuckles 11 of fabrics woven according to the present process are of unequal height. FIGURE 2 illustrates the woven fabric knuckle appear- 15 ance, prior to heat shrinking, resulting from weaving according to the present process with a woof monofilament set angle of zero degrees.

In the practice of the present process warp monofilament polyester fibers having a heat shrinkage potential 20 in FIGURE 1, and of about 10% to about 30%, preferably about 16%, are selected together with woof monofilament polyester fibers having a heat shrinkage potential of about 2% to about 8%, preferably about 4%, for weaving into mono-25 filament polyester fiber fabrics.

Referring now to FIGURE 1, the center line spacing X of the warp monofilament polyester fibers in the loom for weaving is calculated, according to the present invention, from the following equation:

$$X = HE + EJ + FG = 2D\sin\alpha + \frac{2\pi D\cos\alpha}{3} \left(1 - \frac{\alpha}{60}\right)$$

where

D=warp and woof monofilament polyester fiber diam- 35 eter

 $\alpha$ =woof fiber set angle

The distances AB along the curved center line of the woof monofilament fiber, although not drawn to scale, are equal in fabrics before and after heat treatment as 40 designated in FIGURES 1 and 3, and

AE (along the curved woof fiber center line)  $=\frac{\pi D\alpha}{180}$ 

$$EF = \frac{2\pi D}{3} - \frac{2\pi D\alpha}{180} = \frac{2\pi D}{3} \left(1 - \frac{\alpha}{60}\right)$$

$$EJ = EF \cos \alpha = \frac{2\pi D \cos \alpha}{3} \left(1 - \frac{\alpha}{60}\right)$$
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$$HE = FG = D \sin \alpha$$

The equation set forth above provides for a warp filament spacing in the initially woven monofilament polyester fiber fabric which assures that the distance AB along the curved center line of the woof monofilaments provides for knuckles 11 of equal height in the heat shrunk 55 fabric illustrated in FIGURE 3. The above warp spacing equation is applicable with woof fiber weaving set angles  $\alpha$  of 0° to about 40°. As stated above, FIGURE 1 illustrates the woven condition of a monofilament polyester fiber fabric prior to heat shrinkage wherein the set 60 angle  $\alpha$  of the woof filaments is 30°. FIGURE 2 illustrates the woven appearance of a monofilament polyester fiber fabric wherein the set angle  $\alpha$  of the woof fibers is 0°, i.e., the woof fibers are straight.

As previously stated, it is also necessary to specify the 65 caliper of the present woven fabric prior to heat shrinkage in order that equal knuckle heights and minimum free areas be achieved. In the weaving of fabrics, the caliper or thickness of the woven fabric, within the limits imposed by warp and woof fiber diameter, etc., is governed 70 by the degree of beating or "beating in" that is accorded each successive woof filament by the action of the loom. In order to give the weaver a measure of the necessary beating action to result in a satisfactorily woven monofilament polyester fiber fabric for final heat treating accord- 75 source, preferably an infrared bank mounted above and

ing to the present process, the caliper Y of the woven fabric is specified. Using the calculated caliper, the weaver can adjust the beating in of the woof monofilaments to obtain the required caliper and as a result the proper woof monofilament fiber spacing. The woven caliper Y of the present monofilament polyester fiber fabric, before heat treating for shrinkage, is calculated by means of the following formula:

$$Y=3D-(AH+FJ+BG)$$
  
=3D- $\left[2D(1-\cos\alpha)+\frac{2\pi D}{3}\sin\alpha\left(1-\frac{60}{\alpha}\right)\right]$ 

where

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Y=fabric caliper as woven

D=warp and woof monofilament polyester fiber diameter

 $\alpha$ =woof fiber set angle

The vertical distances AH, FJ and BG are illustrated

$$AH = BG = D(1 - \cos \alpha)$$
$$FJ = EF \sin \alpha = \frac{2\pi D}{3} \sin \alpha \left(1 - \frac{60}{\alpha}\right)$$

After weaving, the present monofilament polyester fiber fabric, the as woven fabric is shrunk by heat treating. The heat treating takes advantage of the relative heat shrinkage characteristics of the selected warp and woof polyester monofilaments to produce the present monofilament polyester fiber fabric characterized by dimensional heat stability, equal knuckle heights and minimum free area.

The heat treating or shrinking step is accomplished by tensioning and restraining the as woven monofilament polyester fiber fabric in its lengthwise or warp direction. After tensioning, heat is applied to the fabric in successive treatments of about 5 seconds to about 40 seconds, preferably about 15 seconds per treatment. The fabric temperatures during the successive applications of heat approach gradually the softening point of the selected monofilament polyester fiber. Successive heat treatments are repeated until the monofilament polyester fiber fabric does not shrink further at the treating temperature. The warp and woof monofilament polyester fibers are then "locked up" in the configuration illustrated in FIGURES 3, 6 and 7 wherein the angles  $\beta$  are 90°. In this configuration the heights of the knuckles 11 are equal, and the fabric has a minimum free area. The temperatures of the fibers in the successive heat treating are increased to a maximum temperature immediately below the softening point of the selected fibers. For example, the heat treating temperature used with Treviera fibers is about 360° F. to about 400° F., preferably about 375° F. For dimensional heat stability in use, a sufficient number of successive heating treatments or passes are employed to insure that the monofilament polyester fibers making up the fabric structure have been at the highest heat treating temperature for a total time of about 15 to about 120 seconds. It is noted that some fiber deformation can occur due to the forces engendered by heat treatment; any fiber deformation will tend to decrease the fabric free area.

The heat treatment can, in one preferred embodiment, be effected by sewing together the ends of the as woven monofilament polyester fiber fabric and placing it as an endless belt over two end rolls. A conventional finishing table used in the final steps of metal Fourdrinier wires provides a convenient roll system. The finishing table method of heat treating provides the necessary warp direction restraint while allowing woof direction shrinkage in the fabric. Any convenient heat source, for example an infrared heat bank or a hot oil bath, can be used to provide the required heat. When the endless belt roller system provided by a wire finishing table is used, a heat

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transversely across the fabric undergoing treatment, which infrared bank heats about 4 feet of the fabric length at one time, is convenient. The heat treatment can be carried out by slowly turning the finishing table support rollers so that the entire length of the fabric is brought into operative position with the heat source in successive passes. The increasing temperature at which the fabric is treated during successive heat treating passes is conveniently regulated by providing a heat source operated at the upper temperature limits disclosed and run-10 ning the endless fabric belt faster on initial heat treatment passes than on final heat treatment passes. In this manner the actual monofilament polyester fiber temperature is gradually increased. A means of regulating the heat source temperature can also be employed to effect 15 the gradual increases in monofilament temperature which are desirable to prevent the formation of wrinkles in the fabric during the heat shrinkage treatment. Other combination methods of effecting heat applications of successively increased temperature will be apparent to those 20 persons skilled in heat treating art, and these methods will also be effective in the present process.

The final result of the heat treatments is that the individual warp and woof monofilaments in the fabric attain throughout their diameter temperatures approaching their 25 softening temperature for the specified length of time. This method of heat treating insures the production of a monofilament polyester fiber fabric which is stable under conditions of subsequent use at temperatures up to and including those used in the heat treatment. 30

During heat treatment, the set angle  $\alpha$  of the woof monofilaments in the woven fabric increases due to the retractive forces generated by shrinkage of the warp monofiliaments, and the warp and woof filaments are drawn up and locked in the relative position illustrated in FIGURES 35 3, 6 and 7, where the angle  $\beta$  is 90°, the heights of the knuckles 11 are equal and the free area consisting of the sum of the open areas between the monofilament polyester fibers is at a minimum. The increase in set angle in the woof filaments is accompanied by a decrease in set angle 40 in the warp monofilaments and a decrease in the free area of the monofilament polyester fiber fabric as woven.

The following numerical example illustrates the practice of the present process wherein Treviera-Type P warp monofilament polyester fibers having a diameter of 0.01575 inch and a heat induced shrinkage of 16% are selected. Triviera polyesters result broadly from the reaction of ethylene glycol with terephthalic acid. The woof monofilament polyester fibers for this example are Treviera-Type PRN fibers having a diameter of 0.01575 inch and a heat induced shrinkage potential of 4%, and the woof monofilament polyester fiber set angle  $\alpha$  is 30°.

Using the equation for warp fiber spacing X set forth above:

$$X=2D \sin \alpha + \frac{2\pi D \cos \alpha}{3} \left( -\frac{\alpha}{60} \right)$$
  

$$X=2(0.01575)(0.5) + \frac{2\pi (0.01575)(0.866)}{3} \left( 1 - \frac{(30)}{60} \right)$$
  

$$X=0.030 \text{ inch}$$

Accordingly, the selected warp monofilament polyester fibers are spaced in the loom for weaving at center line distances of 0.030 inch.

The as woven caliper Y of the monofilament polyester fiber fabric, and as a result the woof monofilament polyester fiber spacing, is obtained by using the equation for initial fabric caliper set forth above:

$$Y=3D - \left[2D(1-\cos \alpha) + \frac{2\pi D}{3}\sin \alpha \left(1-\frac{\alpha}{60}\right)\right]$$
  

$$Y=3(0.01575) - \left[2(0.01575)(1-0.866) + \frac{2\pi(0.01575)}{3}(0.5)\left(1-\frac{30}{60}\right)\right]$$
  

$$Y=0.035 \text{ inch}$$

Accordingly, the loom is placed in weaving operation, and the beating force is set to result in a fabric caliper Y of 0.035 inch.

The woven monofilament polyester fiber fabric is removed from the loom and the two fabric ends are joined 5 by sewing to form an endless fabric belt. The endless fabric belt is mounted on the two rolls of a wire finishing table. A bank of infrared lamps having a warp direction length of 40 inches and extending across the fabric width is mounted in operative position above the belt. The bank of infrared lamps is capable of providing an ultimate monofilament polyester fiber temperature in the fabric of 385° F. After mounting the woven monofilament polyester fiber fabric on the wire finishing table rolls, the rolls are positioned to place the endless fabric belt in tension, and the rolls are revolved to give a linear belt speed of 24 feet per minute. With the fabric belt in motion, the infrared bank is turned on, and the fabric thereafter makes ten complete passes under the infrared bank. During the successive passes of the fabric under the infrared bank, the linear speed of the rolls is gradually reduced to a linear speed of 12 feet per minute. In the final passes of the fabric underneath the infrared bank, an utilmate fabric temperature of 385° F. is achieved. The monofilament polyester fiber fabric is then heat shrunk and dimensionally stable in subsequent use up to the ultimate heat treating temperature.

The heat treated monofilament polyester fiber fabric is characterized by equal knuckle heights and a minimum 30 free area of about 16% and has the appearance illustrated in FIGURES 3, 6 and 7.

FIGURES 8, 9, 10 and 11 are provided to illustrate the importance of adherence to the calculated warp monofilament polyester fiber spacing X in the practice of the present process. FIGURE 8 illustrates an enlarged crosssectional view of knuckle cross-over points and knuckles 11, prior to heat treating, in a monofilament polyester fiber fabric woven with a warp spacing X', which warp spacing X' is 20% less than the warp monofilament polyester fiber spacing X calculated for the present process. FIGURE 9 illustrates the knuckle cross-over points and knuckles 11 of FIGURE 8 subsequent to heat treatment. The knuckles 11 illustrated in FIGURE 9 are of unequal height. The woof monofilament polyester fiber knuckles are lower than the warp monofilament polyester fiber knuckles by distance  $\Delta$ , and the monofilament polyester fiber fabric of FIGURE

9 fails to meet the present criteria of equal knuckle height. FIGURE 10 illustrates an enlarged cross-sectional view of knuckle cross-over points and knuckles 11, prior to heat treating, in a monofilament polyester fiber fabric 50 woven with a warp spacing X'', which warp spacing X'' is 20% greater than the warp monofilament fiber spacing X calculated for the present process. FIGURE 11 illustrates an enlarged cross-sectional view of knuckles 11 of FIG-URE 10 subsequent to heat treatment. The knuckles 11 55 illustrated in FIGURE 11 are of unequal height. The woof monofilament polyester fiber knuckles are higher than warp monofilament polyester fiber knuckles by distance  $\Delta'$ , and the monofilament polyester fiber fabric of FIGURE 11, like that of FIGURE 9, fails to meet the present criteria of equal knuckle height.

Applicant prefers to weave the present monofilament polyester fiber fabric in such a way that the as woven woof set angle  $\alpha$  is about 30°, but as illustrated in FIGURE 2 the woof set angle of the as woven monofilament polyester fiber fabric can be 0°, i.e., the woof monofilament polyester fiber can be straight instead of crimped. The disclosed equation for determining the initial warp spacing and the as woven fabric caliper are valid for woof set 70 angles  $\alpha$  of about 0° to about 40° to produce the herein described monofilament polyester fiber fabric product. Also, applicant prefers, as a matter of convenience, to use the wire finishing table roller method of fabric tensioning together with an infrared source for heat treatment. A set 75 heat treating source temperature together with decreasing fabric speeds in successive heat treating passes is also convenient, although other methods of restraining the warp ends of the fabric and applying heat will be found efficious.

It is to be understood that the forms of the invention herein illustrated and described are to be taken as preferred embodiments. Various changes may be made in the weaving process and the heat treating step without departing from the spirit or scope of the invention as defined in the attached claims. In particular it is noted that the principles of the present process can be applied to warp and 10 woof monofilaments of slightly different diameters while still achieving the present beneficial results.

The present process for monofilament polyester fiber fabric weaving and heat treating has been found to be particularly advantageous in the production of carrier 15 fabrics for papermaking and other web forming operations. In particular, the equal knuckle heights engendered in the monofilament polyester fiber fabric product are advantageous in promoting fabric life where the fabric encounters conditions leading to surface wear or abrasion. 20 The equal knuckle height feature insures that no single knuckle in a given fabric area will receive initial wear and thusly become weakened and subject to breakage prior to wear on all other knuckles of the fabric. The minimum free area feature of the present monofilament 25 polyester fiber fabric is advantageous in that it enhances support of a fibrous web to result in a smoother paper surface and maximum contact with a drying surface. Dimensional heat stability ensures the operability of the product fabrics in web drying systems. Applicant is aware 30 of no other process for producing a monofilament polyester fiber fabric with equal knuckle heights which fabric product also exhibits the low free area of the presently disclosed fabric.

Having thus defined and described the invention, what 35 is claimed is:

1. A process for the production of plain weave monofilament polyester fiber fabrics, which process comprises the steps of:

- (1) selecting warp and woof polyester monofilament 40fibers of substantially equal diameter, which warp polyester monofilament fibers have a heat shrinkage potential of about 10% to about 30% and which woof polyester monofilament fibers have a heat shrinkage potential of about 2% to about 8%. 45
- (2) spacing said warp fibers in a loom according to the center line spacing calculated from the equation:

$$X = 2D \sin \alpha + \frac{2\pi D \cos \alpha}{3} \left( 1 - \frac{\alpha}{60} \right)$$
 50

wherein

X=warp fiber center line spacing

- D=warp and woof polyester monofilament fiber di-55 free areas of about 14% to about 20% are produced. ameter, and
- $\alpha$ =woof fiber set angle as woven and is 0° to about 40°
- (3) beating in said woof fibers in said loom to weave monofilament polyester fiber fabrics having an as 60 woven fabric caliper calculated from the equation:

$$Y = 3D - \left[2D(1 - \cos \alpha) + \frac{2\pi D}{3}\sin \alpha \left(1 - \frac{\alpha}{60}\right)\right]$$

wherein

Y=fabric caliper as woven

- D=warp and woof polyester monofilament fiber diameter, and
- 70 $\alpha$ =woof fiber set angle as woven and is 0° to about 40°
- (4) restraining in tension the warp ends of the monofilament polyester fiber fabrics woven in step 3 to allow free shrinkage in the woof direction, and

(5) treating the restrained monofilament polyester fiber fabrics of step 4 with heat in successive steps at temperatures approaching the softening temperature of said warp and woof polyester monofilament fibers,

whereby dimensionally heat stable monofilament polyester fiber fabrics characterized by equal knuckle heights and minimum free areas are produced.

2. The process for the production of plain weave monofilament polyester fabrics of claim 1 wherein the warp and woof polyester monofilament fibers have a diameter of about 0.008 inch to about 0.020 inch.

3. A process for the production of plain weave monofilament polyester fiber fabrics, which process comprises the steps of:

- (1) selecting warp and woof polyester monofilament fibers having equal diameters of about 0.008 inch to about 0.020 inch, which warp polyester monofilament fibers have a heat shrinkage potential of about 16% and which woof polyester monofilament fibers have a heat shrinkage potential of about 4%,
- (2) spacing said warp fibers in a loom according to the center line spacing calculated from the equation:

$$X = 2D \sin \alpha + \frac{2\pi D \cos \alpha}{3} \left( 1 - \frac{\alpha}{60} \right)$$

wherein

X=warp fiber center line spacing

D=warp and woof polyester monofilament fiber diameter, and

 $\alpha$ =woof fiber set angle as woven and is about 30°

(3) beating in said woof fibers in said loom to weave monofilament polyester fiber fabrics having an as woven fabric caliper calculated from the equation:

$$Y = 3D - \left[2D(1 - \cos \alpha) + \frac{2\pi D}{3}\sin \alpha \left(1 - \frac{\alpha}{60}\right)\right]$$

wherein

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Y=fabric caliper as woven

D=warp and woof polyester monofilament fiber diameter, and

 $\alpha$ =woof fiber set angle as woven and is about 30°

(4) restraining in warp direction tension, as endless belts mounted on finishing table rollers, the monofilament polyester fiber fabrics woven in step 3, and

(5) treating the restrained monofilament polyester fiber fabrics of step 4 with heat in successive steps at temperatures approaching the softening temperature of said warp and woof polyester monofilament fibers, whereby dimensionally heat stable monofilament polyester fiber fabrics characterized by equal knuckle heights and

4. The process for the production of plain weave monofilament polyester fabrics of claim 3 wherein the warp and

woof monofilament fibers have a diameter of about 0.01575 inch and dimensionally heat stable monofilament polyester fiber fabrics having free areas of about 16% are produced.

5. A monofilament polyester fiber fabric of plain weave having warp and woof monofilament polyester fibers of substantially equal diameter, which monofilament polyester fabric has a free area of about 14% to about 20% and is further characterized by dimensional heat stability and equal knuckle heights.

6. A monofilament polyester fiber fabric of plain weave having warp and woof monofilament polyester fibers of equal diameters of about 0.008 inch to about 0.020 inch, which monofilament polyester fiber fabric has a free area of about 14% to about 20% and is further characterized by dimensional heat stability and equal knuckle heights. 7. The monofilament polyester fiber fabric of claim 6 75 wherein the warp and woof monofilament polyester fibers

have diameters of about 0.01575 inch, and the monofilament polyester fiber fabric has a free area of about 16%.

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