IN THE UNITED STATES DISTRICT COURT
FOR THE EASTERN DISTRICT OF PENNSYLVANIA

AstenJohnson, Inc. 4399 Corporate Road Charleston, South Carolina 29423 Plaintiff, v. Tamfelt Corporation P.O. Box 427 FIN-33101 Tampere FINLAND Defendant.	:	Civil Action No. _____ COMPLAINT FOR PATENT INFRINGEMENT DEMAND FOR JURY TRIAL

COMPLAINT

PARTIES

1. AstenJohnson, Inc., is a corporation organized and existing under the laws of the State of Delaware with its principal place of business at 4399 Corporate Road, Charleston, South Carolina 29423, hereinafter referred to as the "Plaintiff."

2. Upon information and belief, Tamfelt Corporation is a foreign corporation organized and existing under the laws of Finland with its principal place of business at Tampere, Finland, hereinafter referred to as the "Defendant."

3. Upon information and belief, Tamfelt PMC, Inc. of Canton, Massachusetts is Defendant's domestic agent.

JURISDICTION

4. This action arises out of the patent laws of the United States, Title 35, United States Code, and this Court has jurisdiction under Title 28, United States Code Section 1338(a).

5. Venue is properly laid in this judicial district pursuant to Title 28, United States Code, Section 1391(d).

COUNT I

6. On April 14, 1992, United States Letters Patent No. 5,103,874 ('874 patent"), entitled Papermakers Fabric with Stacked Machine Direction Yarns, was duly and legally issued to Plaintiff as the assignee thereof. A true and correct copy of the '874 patent is attached hereto as Exhibit "A" and is incorporated herein by reference.

7. On June 22, 1995, Plaintiff recorded at the United States Patent and Trademark Office, at Reel No. 7527 and Frame No. 0251, its December 21, 1994 name change from Asten Group, Inc. to Asten, Inc. and on January 4, 2000 Plaintiff recorded at the United States Patent and Trademark Office, at Reel No. 10506 and Frame No. 0009, its September 9, 1999 name change from Asten, Inc. to AstenJohnson, Inc.

8. Plaintiff has continuously been the owner of the entire right, title and interest in and to the '874 patent.

9. On December 1, 1992, United States Letters Patent No. 5,167,261 ('261 patent"), entitled Papermakers Fabric with Stacked Machine Direction Yarns of a High Warp, was duly and legally issued to Plaintiff as the assignee thereof. A true and correct copy of the '261 patent is attached hereto as Exhibit "B" and is incorporated herein by reference.

10. On June 22, 1995, Plaintiff recorded at the United States Patent and Trademark Office, at Reel No. 7527 and Frame No. 0251, its December 21, 1994 name change from Asten Group, Inc. to Asten, Inc. and on January 4, 2000 Plaintiff recorded at the United States Patent and Trademark Office, at Reel No. 10506 and Frame No. 0009, its September 9, 1999 name change from Asten, Inc. to AstenJohnson, Inc.

11. Plaintiff has continuously been the owner of the entire right, title and interest in and to the '261 patent.

12. On July 8, 1997, United States Letters Patent No. 5,645,112 ('112 patent"), entitled Papermakers Fabric with Alternating Crimped CMD Yarns, was duly and legally issued to Plaintiff as the assignee thereof. A true and correct copy of the '112 patent is attached hereto as Exhibit "C" and is incorporated herein by reference.

13. On June 22, 1995, Plaintiff recorded at the United States Patent and Trademark Office, at Reel No. 7527 and Frame No. 0251, its December 21, 1994 name change from Asten Group, Inc. to Asten, Inc. and on January 4, 2000 Plaintiff recorded at the United States Patent and Trademark Office, at Reel No. 10506 and Frame No. 0009, its September 9, 1999 name change from Asten, Inc. to AstenJohnson, Inc.

14. Plaintiff has continuously been the owner of the entire right, title and interest in and to the '112 patent.

15. Defendant has had prior written notice of its infringement.

16. Upon information and belief, Defendant has been and is still infringing the '874, '261 and '112 patents by contributing to or actively inducing the selling, offering for sale, importation or use of the claimed inventions in the United States all in violation of 35 U.S.C. § 271.

17. As a result of Defendant's willful, wanton and deliberate acts, Plaintiff has suffered and will continue to suffer irrevocable damages in its trade and business.

18. As a result of Defendant's willful, wanton and deliberate acts, Plaintiff has suffered monetary damages by reason of the Defendant's infringement, the amount of which is presently unknown.

PRAYER FOR RELIEF

WHEREFORE, Plaintiff prays for the following relief:

A. A preliminary and a final permanent injunction against the Defendant, its agents, servants, employees, and all persons in active concert or participation with, through or under Defendant against continued infringement pursuant to the provisions of 35 U.S.C. § 283.

B. An award of damages, yet to be determined by an accounting, against Defendant sufficient to compensate Plaintiff for its damages pursuant to the provisions of 35 U.S.C. § 284.

C. An order trebling the amount of such damages determined under paragraph B above pursuant to the provisions of 35 U.S.C. § 284.

D. An award of Plaintiff's costs, expenses, attorneys fees and post-judgment and pre-judgment interest pursuant to the provisions of 35 U.S.C. §§ 284 and 285.

E. Such other relief as this Court deems just and equitable.

JURY TRIAL DEMAND

Plaintiff hereby demands trial by jury of all issues properly tried to a jury.

Respectfully submitted,

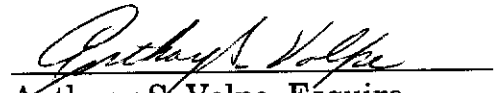

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Exhibit A

US005103874A

United States Patent [19]

Lee

[11] Patent Number: 5,103,874

[45] Date of Patent: Apr. 14, 1992

[54] **PAPERMAKERS FABRIC WITH STACKED MACHINE DIRECTION YARNS**

[75] Inventor: **Henry J. Lee**, Summerville, S.C.

[73] Assignee: **Asten Group, Inc.**, Charleston, S.C.

[21] Appl. No.: **534,164**

[22] Filed: **Jun. 6, 1990**

[51] **Int. Cl.**[5] **D03D 13/00**; D03D 15/00

[52] **U.S. Cl.** ..... **139/383 A**

[58] **Field of Search** ..... 139/383 A, 425 A, 383 AA; 162/DIG. 1, 358

[56] **References Cited**

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4,824,525	4/1989	Penven .	
4,846,231	7/1989	Penven .	
4,883,096	11/1989	Penven .	
4,921,750	5/1990	Todd	139/383 A X

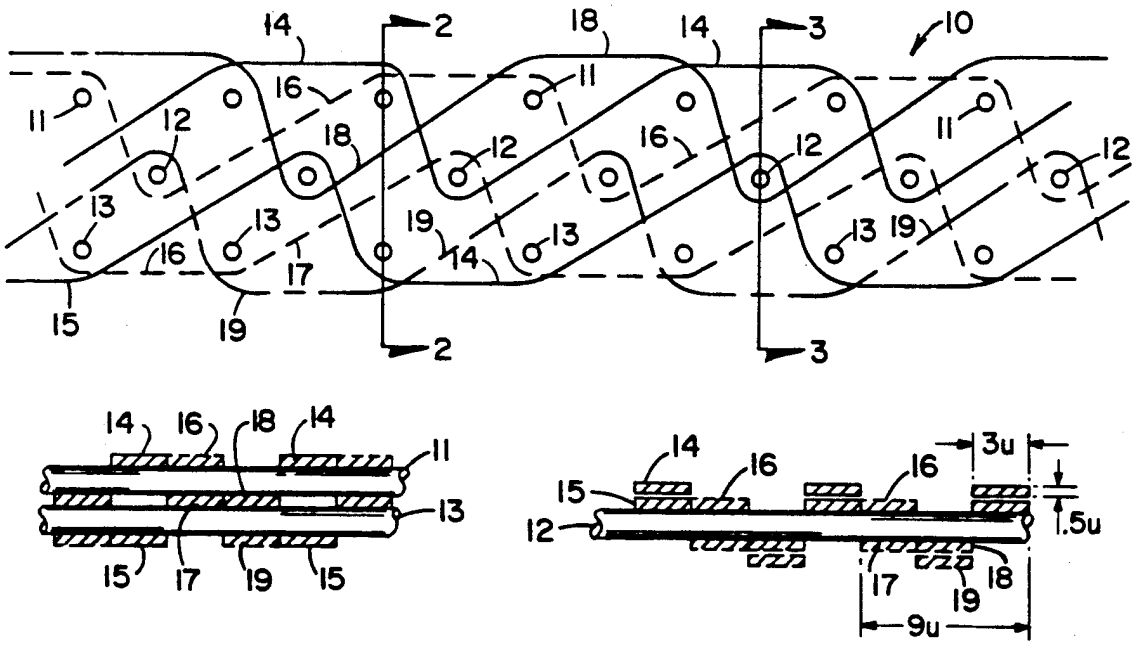
Primary Examiner—Andrew M. Falik

Attorney, Agent, or Firm—Volpe and Koenig

[57] **ABSTRACT**

A papermakers fabric have a system of flat monofilament machine direction yarns (hereinafter MD yarns). The system of MD yarns comprises upper and lower yarns which are vertically stacked. Preferably, the upper MD yarns define floats on the upper surface of the fabric and each upper MD yarn is paired in vertically stacked orientation with a lower MD yarn. At least the upper MD yarns are flat monofilament yarns woven contiguous with each other to reduce the permeability of the fabric and to lock in the machine direction alignment of the stacking pairs of MD yarns. The stacked, contiguous woven machine direction system provides stability and permits the MD yarns to have a relatively high aspect ratio, cross-sectional width to height, of greater than 3:1. A seam for the fabric comprised of loops formed from selected flat MD yarns is provided to render the fabric endless during use in papermaking.

48 Claims, 3 Drawing Sheets



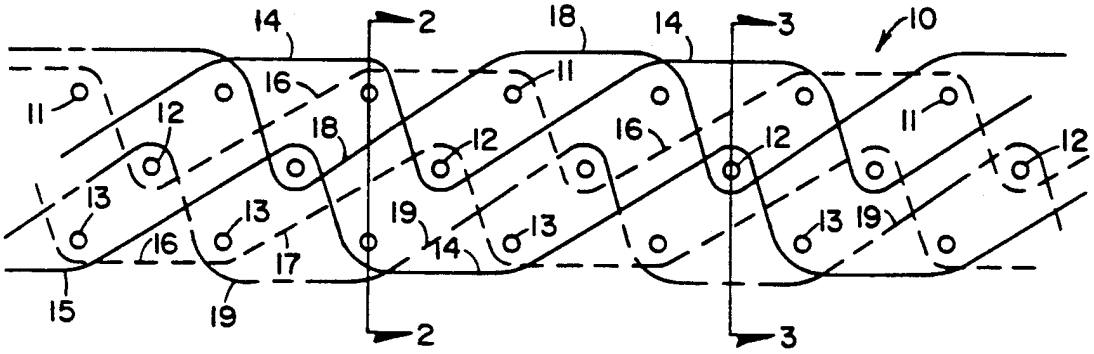


FIG. 1

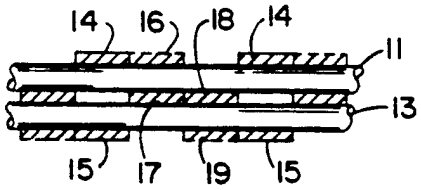


FIG. 2

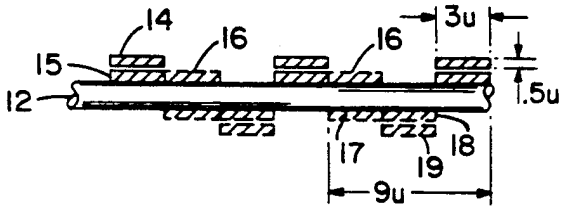


FIG. 3

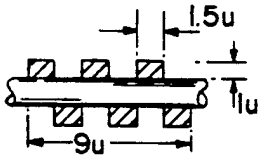


FIG. 4
PRIOR ART

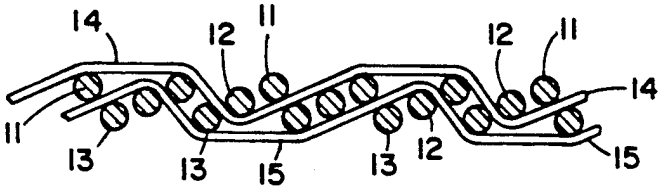


FIG. 5

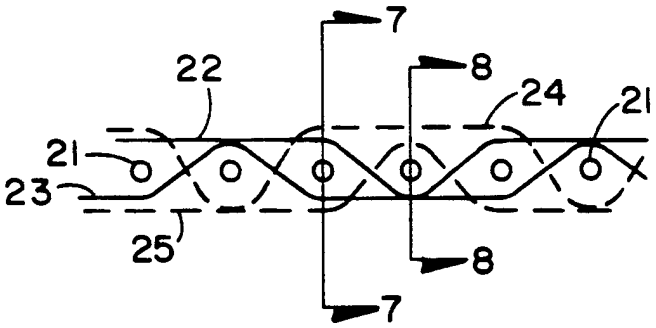


FIG. 6

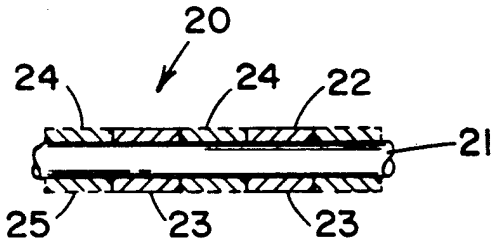


FIG. 7

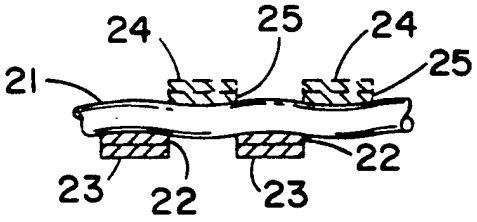


FIG. 8

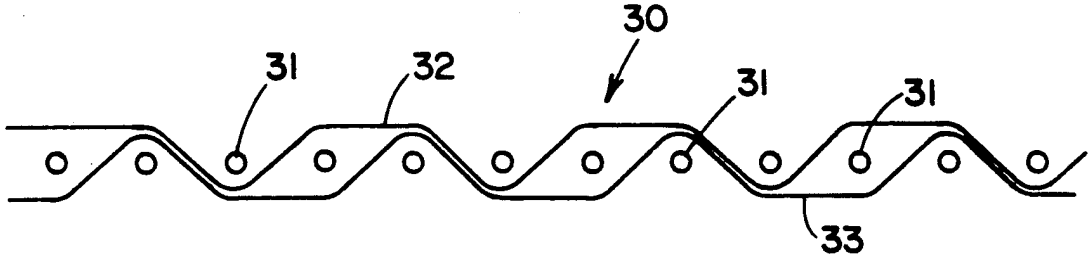


FIG. 9

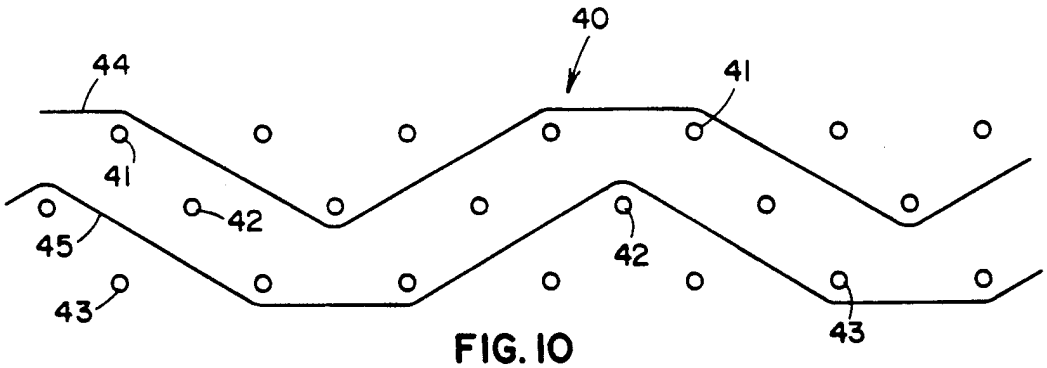


FIG. 10

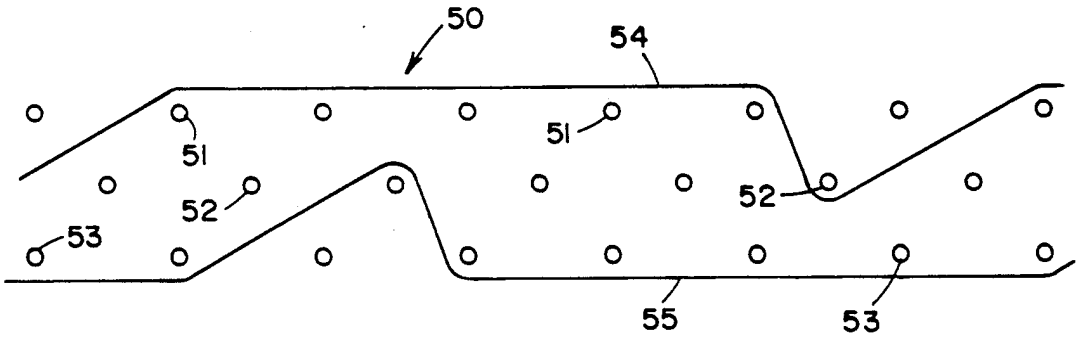


FIG. 11

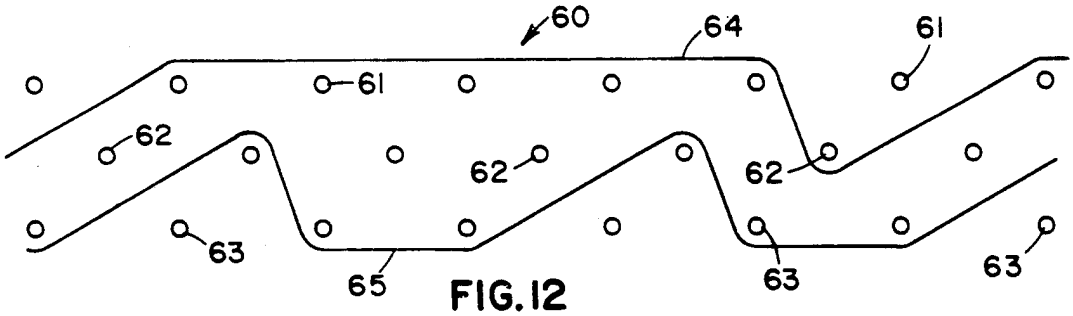


FIG. 12

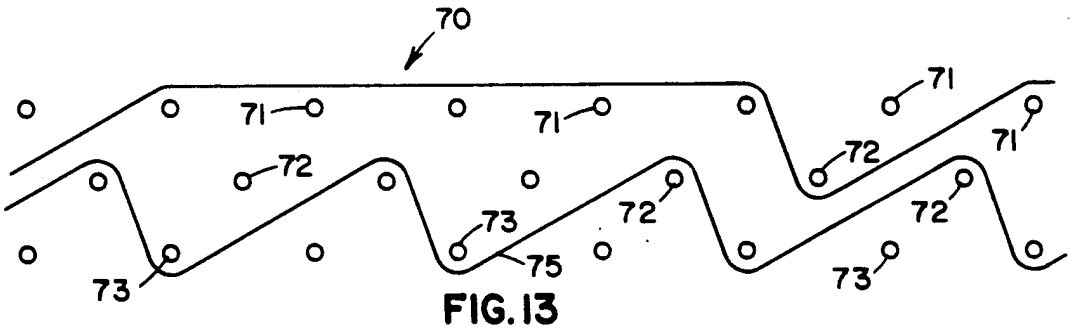


FIG. 13

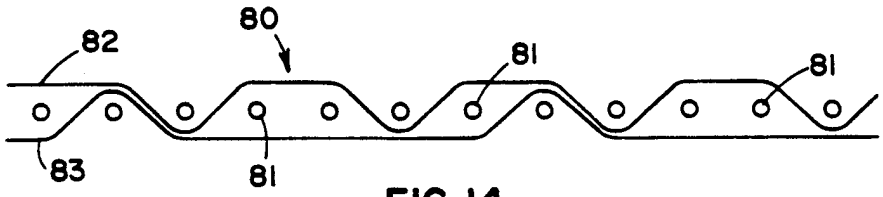


FIG. 14

PAPERMAKERS FABRIC WITH STACKED MACHINE DIRECTION YARNS

The present invention relates to papermakers fabrics and in particular to fabrics comprised of flat monofilament yarns.

BACKGROUND OF THE INVENTION

Papermaking machines generally are comprised of three sections: forming, pressing, and drying. Papermakers fabrics are employed to transport a continuous paper sheet through the papermaking equipment as the paper is being manufactured. The requirements and desirable characteristics of papermakers fabrics vary in accordance with the particular section of the machine where the respective fabrics are utilized.

With the development of synthetic yarns, shaped monofilament yarns have been employed in the construction of papermakers fabrics. For example, U.S. Pat. No. 4,290,209 discloses a fabric woven of flat monofilament warp yarns; U.S. Pat. No. 4,755,420 discloses a non-woven construction where the papermakers fabric is comprised of spirals made from flat monofilament yarns.

Numerous weaves are known in the art which are employed to achieve different results. For example, U.S. Pat. No. 4,438,788 discloses a dryer fabric having three layers of cross machine direction yarns interwoven with a system of flat monofilament machine direction yarns such that floats are created on both the top and bottom surfaces of the fabric. The floats tend to provide a smooth surface for the fabric.

Permeability is an important criteria in the design of papermakers fabrics. In particular, with respect to fabrics made for running at high speeds on modern drying equipment, it is desirable to provide dryer fabrics with relatively low permeability.

U.S. Pat. No. 4,290,209 discloses the use of flat monofilament warp yarns woven contiguous with each other to provide a fabric with reduced permeability. However, even where flat warp yarns are woven contiguous with each other, additional means, such as stuffer yarns, are required to reduce the permeability of the fabric. As pointed out in that patent, it is desirable to avoid the use of fluffy, bulky stuffer yarns to reduce permeability which make the fabric susceptible to picking up foreign substances or retaining water.

U.S. Pat. No. 4,290,209 and U.S. Pat. No. 4,755,420 note practical limitations in the aspect ratio (cross-sectional width to height ratio) of machine direction warp yarns defining the structural weave of a fabric. The highest practical aspect ratio disclosed in those patents is 3:1, and the aspect ratio is preferably, less than 2:1.

U.S. Pat. No. 4,621,663, assigned to the assignee of the present invention, discloses one attempt to utilize high aspect ratio yarns (on the order of 5:1 and above) to define the surface of a papermakers dryer fabric. As disclosed in that patent, a woven base fabric is provided to support the high aspect ratio surface yarns. The woven base fabric is comprised of conventional round yarns and provides structural support and stability to the fabric disclosed in that patent.

U.S. Pat. No. 4,815,499 discloses the use of flat yarns in the context of a forming fabric. That patent discloses a composite fabric comprised of an upper fabric and a lower fabric tied together by binder yarns. The aspect ratio employed for the flat machine direction yarns in both the upper and lower fabrics are well under 3:1.

SUMMARY AND OBJECTS INVENTION

The present invention provides a papermakers fabric having a system of flat monofilament machine direction yarns (hereinafter MD yarns) which are stacked to control the permeability of the fabric. The present weave also provides for usage of high aspect ratio yarns as structural weave components. The system of MD yarns comprises upper and lower yarns which are vertically stacked. Preferably, the upper MD yarns define floats on the upper surface of the fabric and each upper MD yarn is paired in a vertically stacked orientation with a lower MD yarn. The lower MD yarns may weave in an inverted image of the upper MD yarns to provide floats on the bottom fabric surface or may weave with a different repeat to provide a different surface on the bottom of the fabric.

At least the upper MD yarns are flat monofilament yarns woven contiguous with each other to reduce the permeability of the fabric and to lock in the machine direction alignment of the stacking pairs of MD yarns. In the preferred embodiment, the same type and size yarns are used throughout the machine direction yarn system and both the top and the bottom MD yarns weave contiguously with adjacent top and bottom MD yarns, respectively. The stacked, contiguous woven machine direction system provides stability and permits the MD yarns to have a relatively high aspect ratio, cross-sectional width to height, of greater than 3:1.

It is an object of the invention to provide a papermakers fabrics having permeability controlled with woven flat machine direction yarns.

It is a further object of the invention to provide a low permeability fabric constructed of all monofilament yarns without the use of bulky stuffer yarns and without sacrificing strength or stability.

Other objects and advantages will become apparent from the following description of presently preferred embodiments.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is a schematic diagram of a papermakers fabric made in accordance with the teachings of the present invention;

FIG. **2** is a cross-sectional view of the fabric depicted in FIG. **1** along line **2—2**;

FIG. **3** is a cross-sectional view of the fabric depicted in FIG. **1** along line **3—3**;

FIG. **4** is a cross-sectional view of a prior art weave construction;

FIG. **5** illustrates the actual yarn structure of the fabric depicted in FIG. **1** in the finished fabric showing only two representative stacked MD yarns;

FIG. **6** is a schematic view of a second embodiment of a fabric made in accordance with the present invention;

FIG. **7** is a cross-sectional view of the fabric depicted in FIG. **6** along line **7—7**;

FIG. **8** is a cross-sectional view of the fabric depicted in FIG. **6** along line **8—8**;

FIG. **9** is a schematic view of a third alternate embodiment of a fabric made in accordance with the teachings of the present invention showing only one pair of stacked MD yarns;

FIG. **10** is a schematic view of a fourth alternate embodiment of a fabric made in accordance with the

teachings of the present invention showing only one pair of stacked MD yarns;

FIG. **11** is a schematic view of a fifth alternate embodiment of a fabric made in accordance with the teachings of the present invention showing only one pair of stacked MD yarns;

FIG. **12** is a schematic view of a sixth alternate embodiment of a fabric made in accordance with the teachings of the present invention showing only one pair of stacked MD yarns;

FIG. **13** is a schematic view of a seventh alternate embodiment of a fabric made in accordance with the teachings of the present invention showing only one pair of stacked MD yarns; and

FIG. **14** is a schematic view of a eighth alternate embodiment of a fabric made in accordance with the teachings of the present invention showing only one pair of stacked MD yarns.

DETAILED DESCRIPTION OF PRESENTLY PREFERRED EMBODIMENTS

Referring to FIGS. **1**, **2**, and **3**, there is shown a papermakers dryer fabric **10** comprising upper, middle and lower layers of cross machine direction (hereinafter CMD) yarns **11**, **12**, **13**, respectively, interwoven with a system of MD yarns **14–19** which sequentially weave in a selected repeat pattern. The MD yarn system comprises upper MD yarns **14**, **16**, **18** which interweave with CMD yarns **11**, **12** and lower MD yarns **15**, **17**, **19** which interweave with CMD yarns **12**, **13**.

The upper MD yarns **14**, **16**, **18** define floats on the top surface of the fabric **10** by weaving over two upper layer CMD yarns **11** dropping into the fabric to weave in an interior knuckle under one middle layer CMD yarn **12** and under one CMD yarn **11** and thereafter rising to the surface of the fabric to continue the repeat of the yarn. The floats over upper layer CMD yarns **11** of upper MD yarns **14**, **16**, **18** are staggered so that all of the upper and middle layer CMD yarns **11**, **12** are maintained in the weave.

As will be recognized by those skilled in the art, the disclosed weave pattern with respect to FIGS. **1**, **2**, and **3**, results in the top surface of the fabric having a twill pattern. Although the two-float twill pattern represented in FIGS. **2**, and **3** is a preferred embodiment, it will be recognized by those of ordinary skill in the art that the length of the float, the number of MD yarns in the repeat, and the ordering of the MD yarns may be selected as desired so that other patterns, twill or non-twill, are produced.

As best seen in FIGS. **2** and **3**, lower MD yarns **15**, **17**, **19**, weave directly beneath upper MD yarns **14**, **16**, **18**, respectively, in a vertically stacked relationship. Accordingly, the upper and lower MD yarns are paired and weave throughout the body of the fabric with the same relative vertical stacked alignment. For example, with respect to yearn pair **14**, **15**, compare FIGS. **2** and **3** with FIGS. **1** and **5**. As noted below, portions of the stacked yarns are preferably removed proximate the ends of the fabric to facilitate the creation of a seam.

It will be understood to those of ordinary skill in the art that upper and lower as used herein are relative terms defining the relationship of the yarns within the fabric. In use, papermakers fabrics travel a serpentine path and the orientation of any particular portion of a fabric changes accordingly as it follows that path.

The lower yarns weave in an inverted image of their respective upper yarns. Each lower MD yarn **15**, **17**, **19** floats under two lower layer CMD yarns **13**, rises into the fabric over one CMD yarn **13** and forms a knuckle around one middle layer CMD yarn **12** whereafter the yarn returns to the lower fabric surface to continue its repeat floating under the next two lower layer CMD yarns **13**.

With respect to each pair of stacked yarns, the interior knuckle, formed around the middle layer CMD yarns **12** by one MD yarn, is hidden by the float of the other MD yarn. For example, in FIGS. **1** and **3**, lower MD yarn **15** is depicted weaving a knuckle over CMD yarn **12** while MD yarn **14** is weaving its float over CMD yarns **11**, thereby hiding the interior knuckle of lower MD yarn **15**. Likewise, with respect to FIGS. **1** and **3**, upper MD yarn **18** is depicted weaving a knuckle under yarn CMD yarn **12** while it is hidden by lower MD yarn **19** as it floats under CMD yarns **13**.

The upper MD yarns **14**, **16**, **18**, are woven contiguous with respect to each other. This maintains their respective parallel machine direction alignment and reduces permeability. Such close weaving of machine direction yarns is known in the art as 100% warp fill as explained in U.S. Pat. No. 4,290,209. As taught therein (and used herein), actual warp count in a woven fabric may vary between about 80%–125% in a single layer and still be considered 100% warp fill.

The crowding of MD yarns **14**, **16**, and **18** also serves to force MD yarns **15**, **17**, **19**, into their stacked position beneath respective MD yarns **14**, **16**, **18**. Preferably MD yarns **15**, **17**, and **19** are the same size as MD yarns **14**, **16**, and **18** so that they are likewise woven 100% warp fill. This results in the overall fabric of the preferred embodiment having 200% warp fill of MD yarns.

Since the lower MD yarns **15**, **17**, **19** are also preferably woven 100% warp fill, they likewise have the effect of maintaining the upper MD yarns **14**, **16**, **18** in stacked relationship with the respect to lower MD yarns **15**, **17**, **19**. Accordingly, the respective MD yarn pairs **14** and **15**, **16** and **17**, **18** and **19** are doubly locked into position thereby enhancing the stability of the fabric.

As set forth in the U.S. Pat. No. 4,290,209, it has been recognized that machine direction flat yarns will weave in closer contact around cross machine direction yarns than round yarns. However, a 3:1 aspect ratio, i.e. the ratio of cross-sectional width to height, was viewed as a practical limit for such woven yarns in order to preserve overall fabric stability. The present stacked MD yarn system preserves the stability and machine direction strength of the fabric and enables the usage of yarns with increased aspect ratio to more effectively control permeability.

The high aspect ratio of the MD yarns translates into reduced permeability. High aspect ratio yarns are wider and thinner than conventional flat yarns which have aspect ratios less than 3:1 and the same cross-sectional area. Equal cross-sectional area means that comparable yarns have substantially the same linear strength. The greater width of the high aspect ratio yarns translates into fewer interstices over the width of the fabric than with conventional yarns so that fewer openings exist in the fabric through which fluids may flow. The relative thinness of the high aspect ratio yarns enables the flat MD yarns to more efficiently cradle, i.e. brace, the cross machine direction yarns to reduce the size of the interstices between machine direction and cross machine direction yarns.

For example, as illustrated in FIG. **4**, a fabric woven with a single layer system of a flat machine direction

warp having a cross-sectional width of 1.5 units and a cross-sectional height of 1 unit, i.e. an aspect ratio of 1.5:1, is shown. Such fabric could be replaced by a fabric having the present dual stacked MD yarn system with MD yarns which are twice the width, i.e. 3 units, and half the height, i.e. 0.5 units. Such MD yarns thusly having a fourfold greater aspect ratio of 6:1, as illustrated in FIG. **3**.

The thinner, wider MD yarns more efficiently control permeability while the machine direction strength of the fabric remains essentially unaltered since the cross-sectional area of the MD yarns over the width of the fabric remains the same. For the above example, illustrated by FIGS. **4** and **3**, the conventional single MD yarn system fabric has six conventional contiguous flat yarns over 9 units of the fabric width having a cross-sectional area of 9 square units, i.e. 6*(1 u.*1.5 u.). The thinner, wider high aspect ratio yarns, woven as contiguous stacked MD yarns, define a fabric which has three stacked pairs of MD yarns over 9 units of fabric width. Thus such fabric also has a cross-sectional area of 9 square units, i.e. (3*(0.5 u.*3 u.))+(3*(0.5 u.*3 u.)), over 9 units of fabric width.

In one example, a fabric was woven in accordance with FIGS. **2** and **3**, wherein the CMD yarns **11**, **12**, **13** were polyester monofilament yarns 0.6 mm in diameter interwoven with MD yarns **14–19** which were flat polyester monofilament yarns having a width of 1.12 mm and a height of 0.2 mm. Accordingly, the aspect ratio of the flat MD yarns was 5.6:1. The fabric was woven at 48 warp ends per inch with a loom tension of 40 PLI (pounds per linear inch) and 12.5 CMD pick yarns per inch per layer (three layers).

The fabric was heat set in a conventional heat setting apparatus under conditions of temperature, tension and time within known ranges for polyester, monofilament yarns. For example, conventional polyester fabrics are heat set within parameters of 340° F.–380° F. temperature, 6–15 PLI (pounds per linear inch) tension, and 3–4 minutes time. However, due to their stable structure, the fabrics of the present invention are more tolerant to variations in heat setting parameters.

The fabric exhibited a warp modulus of 6000 PSI (pounds per square inch) measured by the ASTM D-1682-64 standard of the American Society for Testing and Materials. The fabric stretched less that 0.2% in length during heat setting. This result renders the manufacture of fabrics in accordance with the teachings of the present invention very reliable in achieving desired dimensional characteristic as compared to conventional fabrics.

The resultant heat set fabric had 12.5 CMD yarns per inch per layer with 106% MD warp fill with respect to both upper and lower MD yarns resulting in 212% actual warp fill for the fabric. The finished fabric has a permeability of 83 CFM as measured by the ASTM D-737-75 standard.

As illustrated in FIG. **5**, when the fabric **10** is woven the three layers of CMD yarns **11**, **12**, **13** become compressed. This compression along with the relatively thin dimension of the MD yarns reduces the caliper of the fabric. Accordingly, the overall caliper of the fabric can be maintained relatively low and not significantly greater than conventional fabrics woven without stacked MD yarn pairs. In the above example, the caliper of the finished fabric was 0.050 inches.

It will be recognized by those of ordinary skill in the art that if either top MD yarns **14**, **16**, **18** or bottom MD yarns **15**, **17**, **19** are woven at 100% warp fill, the overall warp fill for the stacked fabric will be significantly greater than 100% which will contribute to the reduction of permeability of the fabric. The instant fabric having stacked MD yarns will be recognized as having a significantly greater percentage of a warp fill than fabrics which have an actual warp fill of 125% of non-stacked MD yarns brought about by crowding and lateral undulation of the warp strands. Although the 200% warp fill is preferred, a fabric may be woven having 100% fill for either the upper or lower MD yarns with a lesser degree of fill for the other MD yarns by utilizing yarns which are not as wide as those MD yarns woven at 100% warp fill. For example, upper yarns **14**, **16**, **18** could be 1 unit wide with lower layer yarns **15**, **17**, **19** being 0.75 units wide which would result in a fabric having approximately 175% warp fill.

Such variations can be used to achieve a selected degree of permeability. Alternatively, such variations could be employed to make a forming fabric. In such a case, the lower MD yarns would be woven 100% warp fill to define the machine side of the fabric and the upper MD yarns would be woven at a substantially lower percentage of fill to provide a more open paper forming surface.

Referring to FIGS. **6**, **7** and **8**, there is shown a second preferred embodiment of a fabric **20** made in accordance with the teachings of the present invention. Papermakers fabric **20** is comprised of a single layer of CMD yarns **21** interwoven with a system of stacked MD yarns **22–25** which weave in a selected repeat pattern. The MD yarn system comprises upper MD yarns **22**, **24** which define floats on the top surface of the fabric **20** by weaving over three CMD yarns **21**, dropping into the fabric to form a knuckle around the next one CMD yarn **21**, and thereafter continuing to float over the next three CMD yarns **21** in the repeat.

Lower MD yarns **23**, **25**, weave directly beneath respective upper MD yarns **22**, **24** in a vertically stacked relationship. The lower MD yarns weave in an inverted image of their respective upper MD yarns. Each lower MD yarn **23**, **25** floats under three CMD yarns **21**, weaves upwardly around the next one CMD yarn forming a knuckle and thereafter continues in the repeat to float under the next three CMD yarns **21**.

As can be seen with respect to FIGS. **6** and **8**, the knuckles formed by the lower MD yarns **23**, **25** are hidden by the floats defined by the upper MD yarns **22**, **24** respectively. Likewise the knuckles formed by the upper MD yarns **22**, **24** are hidden by the floats of the lower MD yarns **23**, **25** respectively.

The caliper of the fabric proximate the knuckle area shown in FIG. **8**, has a tendency to be somewhat greater than the caliper of the fabric at non-knuckle CMD yarns **21**, shown in FIG. **7**. However, the CMD yarns **21** around which the knuckles are formed become crimped which reduces the caliper of the fabric in that area as illustrated in FIG. **8**. Additionally, slightly larger size CMD yarns may be used for CMD yarns **21**, shown in FIG. **7**, which are not woven around as knuckles by the MD yarns.

A fabric was woven in accordance with FIGS. **6**, **7** and **8**, wherein the CMD yarns **21** were polyester monofilament yarns 0.7 mm in diameter interwoven with MD yarns **22–25** which were flat polyester monofilament yarns having a width of 1.12 mm and a height of 0.2mm. Accordingly, the aspect ratio of the flat MD yarns was 5.6:1. The fabric was woven at 22 CMD pick

yarns per inch. The fabric was heat set using conventional methods. The fabric exhibited a modulus of 6000 PSI. The fabric stretched less than 0.2% in length during heat setting. The resultant fabric had 22 CMD yarns per inch with 106% MD warp fill with respect to both upper and lower MD yarns resulting in 212% actual warp fill for the fabric. The finished fabric had a caliper of 0.048 inches and an air permeability of 60 CFM.

The preferred inverted image weave of the lower MD yarns facilitates the creation of seaming loops at the end of the fabric which enable the fabric ends to be joined together. In forming a seaming loop, the upper MD yarns extend beyond the end of the fabric and the respective lower yarns are trimmed back a selected distance from the fabric end. The upper MD yarns are then bent back upon themselves and rewoven into the space vacated by the trimmed lower MD yarns. When the upper MD yarns are backwoven into the space previously occupied by the lower MD yarns, their crimp matches the pattern of the lower MD yarns, thereby locking the resultant end loops in position. Similarly, alternate top MD yarns can be backwoven tightly against the end of the fabric such that loops formed on the opposite end of the fabric can be intermeshed in the spaces provided by the non-loop forming MD yarns to seam the fabric via insertion of a pintle through the intermeshed end loops.

Since the top and bottom machine direction yarns are stacked, the resultant end loops are orthogonal to the plane of the fabric surface and do not have any twist. In conventional backweaving techniques, the loop defining yarns are normally backwoven into the fabric in a space adjacent to the yarn itself. Such conventional loop formation inherently imparts a twist to the seaming loop, see U.S. Pat. No. 4,438,788, FIG. 6.

With reference to FIG. **9**, a third embodiment of a papermakers fabric **30** is shown. Fabric **30** comprises a single layer of CMD yarns **31** interwoven with stacked pairs of flat monofilament yarns in a selected repeat pattern. For clarity, only one pair of stacked MD yarns is shown comprising upper MD yarn **32** and lower MD yarn **33**. The upper MD yarns weave in a float over two CMD yarns **31**, form a single knuckle under the next CMD yarn **31** and thereafter repeat. Similarly the lower MD yarns weave in an inverted image of the upper MD yarns weaving under two CMD yarns **31**, forming a knuckle over the next CMD yarn **31** and then returning to the bottom surface of the fabric in the repeat. Since the repeat of both the upper and lower MD yarns is with respect to three CMD yarns **31**, a total of three different stacked pairs of yarns comprise the weave pattern of the MD yarn system.

A fabric was woven in accordance with FIG. **9** wherein the CMD yarns **31** were polyester monofilament yarns 0.7 mm in diameter interwoven with MD yarns which were flat polyester monofilament yarns having a width of 1.12 mm and a height of 0.2 mm. Accordingly, the aspect ratio of the flat MD yarns was 5.6:1. The fabric was woven 48 warp ends per inch under a loom tension of 60 PLI and 18 CMD pick yarns per inch. The fabric was heat set using conventional methods. The fabric exhibited a modulus of 6000 PSI. The fabric stretched less than 0.2% in length during heat setting. The resultant fabric had 18 CMD yarns per inch with 106% MD warp fill with respect to both upper and lower MD yarns resulting in 212% actual warp fill for the fabric. The finished fabric having a caliper of 0.046 inches and an air permeability of 66 CFM.

With reference to FIG. **10**, a fourth embodiment of a papermakers fabric **40** is shown. Fabric **40** comprises upper, middle and lower layers of CMD yarns **41**, **42**, **43**, respectively, interwoven with stacked pairs of flat monofilament yarns in a selected repeat pattern. For clarity, only one pair of stacked MD yarns is shown comprising upper MD yarn **44** and lower MD yarn **45**. The upper MD yarns weave in a float over two upper layer CMD yarns **41**, under the next yarn **41** and a middle layer yarn **42** to form a single knuckle, under the next CMD yarn **41** and thereafter rise to the top surface to continue to repeat. Similarly, the lower MD yarns weave in an inverted image of the upper MD yarns weaving under two lower layer CMD yarns **43** over the next CMD yarn **43** and a middle CMD yarn **42** forming a knuckle, over the next CMD yarn **43** then returning to the bottom surface of the fabric to repeat. Since the repeat of both the upper and lower MD yarns is with respect to four upper and lower CMD yarns **41**, **43**, respectively, a total of four different stacked pairs of yarns comprise the weave pattern of the MD yarn system.

A fabric was woven in accordance with FIG. **10**, wherein the upper and lower layer CMD yarns **41**, **43** were nylon-sheathed, multifilament polyester yarns 0.62 mm in diameter and the middle layer CMD yarns **42** were polyester monofilament yarns 0.5 mm in diameter interwoven with MD yarns **22–25** which were flat polyester monofilament yarns having a width of 0.60 mm and a height of 0.38 mm. Accordingly, the aspect ratio of the flat MD yarns was 1.58:1. The fabric was woven with 96 warp ends per inch under a loom tension of 40 PLI and 15 CMD pick yarns per inch per layer. The fabric was heat set using conventional methods. The resultant fabric had 15 CMD yarns per inch per layer with 113% MD warp fill with respect to both upper and lower MD yarns resulting in 226% actual warp fill for the fabric. The finished fabric had a caliper of 0.075 inches and an air permeability of 60 CFM.

FIGS. **11**, **12** and **13** illustrate the fifth, sixth and seventh embodiments of the present invention. FIG. **11** illustrates the weave of a relatively long float on both sides of the fabric; FIG. **12** illustrates how a stacked pair MD yarn weave can define floats of different lengths on opposite sides of the fabric; and FIG. **13** illustrates how a stacked pair MD yarn weave can be used to construct fabrics having MD knuckles on one side of the fabric.

Relatively long floats predominating the surfaces of a dryer fabric are beneficial for both the paper-carrying side as well as the machine side of the fabric:. On the paper-carrying side, long floats provide greater contact area with the paper sheet for increased heat transfer. On the machine side, long floats provide increased wear surface and contact area to reduce bounce and flutter. The stacked pair MD yarn weave is versatile in allowing different surfaces to be defined on the top and bottom sides of the fabric. Accordingly, fabrics made in accordance with the teachings of the present invention may be used for other industrial purposes such as in the drying of sludge.

With respect to FIG. **11**, a fabric **50** is illustrated comprising three layers of yarns **51**, **52**, and **53** respectively. In this construction, the MD yarn pairs, such as the pair formed by upper layer yarn **54** and lower layer yarn **55**, define relatively long floats on both the top and bottom surfaces of the fabric. Upper yarn **54** weaves

over five upper layer CMD yarns **51**, drops into the fabric to form a knuckle under one middle layer CMD yarn **52**, weaves under the next upper layer yarn **51** and thereafter repeats. Lower MD yarn **55** weaves in an inverted image under five lower layer CMD yarns **53**, rising into the fabric over the next CMD **53** to weave a knuckle over one middle layer CMD yarn **52** thereafter dropping to the bottom surface of the fabric to continue its repeat. In such a construction, six pairs of stacked MD yarns are utilized in the repeat of the fabric and are sequentially woven in a selected sequence to produce a desired pattern on the surfaces of the fabric which will be predominated by the MD yarn floats.

The embodiment shown in FIG. **12** depicts a fabric **60** in which the MD yarns weave with a five-float repeat on the top fabric surface and a two-float repeat on the bottom fabric surface. For example, upper MD yarn **64** interweaves with upper and middle CMD yarns **61**, **62** in the same manner that upper MD yarn **54** weaves with respective CMD yarns **51**, **52** with respect to fabric **50** in FIG. **11**. However, lower MD yarn **65**, which forms a stacked pair with upper MD yarn **64**, weaves in a two-float bottom repeat with respect lower and middle CMD yarns **63**, **62**. For example, lower MD yarn **65** floats under two lower layer CMD yarns **63**, rises above the next CMD yarn **63** to form a knuckle over one middle layer CMD yarn **62** and thereafter drops to the bottom surface of the fabric **60** to continue to repeat. As with the other embodiments discussed above, the interior knuckles formed by the lower MD yarns are hidden by the upper MD yarn of the respective stacked pair and vice-versa.

The construction shown in FIG. **12** permits different surfaces to be defined on the top and bottom of the fabric while utilizing the benefits of the stacked MD yarn pairing.

The embodiment shown in FIG. **13** discloses another example of a fabric **70** having five-float MD yarns predominating the upper surface of the fabric, but with MD knuckles on the lower surface of the fabric. This type of construction may be advantageously used to construct a forming fabric where the upper fabric surface, having relatively long floats, would be used as the machine side of the fabric and the knuckled lower surface of the fabric would be used as the paper forming side.

Fabric **70** includes three layers of CMD yarns **71**, **72**, **73** respectively which interweave with stacked pairs of MD yarns to define this construction. Only one pair of stacked pair of MD yarns **74**, **75** is depicted for clarity. Upper MD yarn **74** weaves in a five-float pattern with respect &:o upper and middle layer CMD yarns **71**, **72** in the same manner as upper MD yarn **54** with respect to fabric **50** shown in FIG. **11**. Lower MD yarn **75** weaves three interior knuckles and three lower surface knuckles with respect to middle and lower layer CMD yarns **72**, **73** under each upper surface float of its respective MD yarn pair yarn **74**. The repeat of the upper MD yarns is defined with respect to six upper layer CMD yarns **71** and the repeat of the lower MD yarns is defined with respect to only two lower layer CMD yarns **73**. Accordingly, there are six different pairs of stacked MD yarns which constitute the MD yarn system which, as noted above, can be arranged such that a desired pattern is formed on the upper surface of the fabric.

Generally for stacked pair weaves, the repeat of the upper MD yarns will be equally divisible by, or an equal multiple of, the repeat of the lower MD yarns in defining the stacking pair relationship. For example, with respect to FIG. **12** the repeat of the upper MD yarns is six upper layer CMD yarns which is equally divisible by the repeat of the lower MD yarns which is three lower layer CMD yarns.

With respect to the eighth alternate embodiment shown in FIG. **14**, a fabric **80** is illustrated having a single layer of CMD yarns **81** and a representative stacked pair of MD yarns **82**, **83**. Upper MD yarn **82** weaves with two floats over CMD yarns **81** with a repeat occurring with respect to three CMD yarns **81**. Lower MD yarn **83** weaves with five floats under CMD yarns **81** with a repeat of six CMD yarns **81**. Thus, in fabric **80**, the repeat of the upper MD yarns, which is three, is an equal multiple of the repeat of lower MD yarns, which is six.

With respect to single layer CMD fabrics made in accordance with the teachings of the present invention, in general, the upper MD yarns repeat with respect to X CMD yarns with a float of Y, where Y is an integer greater than 1 and X is an integer not greater than 2Y, and the lower MD yarns repeat with respect to Z CMD yarns with a float of W where Z is an integer which is an equal multiple of, or equally divisible by, X and W is an integer greater than 1 and is not less than half of Z.

A variety of other weave patterns employing the paired stacked weave construction of the instant invention may be constructed within the scope of the present invention. For example, in some applications it may be desirable to have MD yarn surface floats over six or more CMD yarns. Such fabrics are readily constructed in accordance with the teachings of the present invention.

What I claim is:

1. A papermakers fabric comprising:

a system of CMD yarns including at least upper and lower layers of CMD yarns;

a system of flat monofilament MD yarns interwoven with said CMD yarns in a selected repeat pattern;

said MD yarn system having paired upper and lower yarns that are stacked in the same relative vertical alignment to each other throughout the body of the fabric; and

at least said upper MD yarns are 100% warp fill.

2. A papermakers fabric according to claim **1** wherein said upper MD yarns are interwoven with floats over a selected number of said upper layer CMD yarns such that the upper surface of the fabric is predominated by said upper MD yarn floats.

3. A papermakers fabric according to claim **2** wherein said lower MD yarns are interwoven with said CMD yarns in an inverted image of the repeat of the respective upper MD yarns of said MD yarn pairs whereby the bottom surface of the fabric is also predominated by floats of said MD yarns.

4. A papermakers fabric according to claim **3** wherein said CMD yarn system further includes a middle layer of CMD yarns and wherein said MD yarns interweave with said middle layer CMD yarns with hidden interior knuckles.

5. A papermakers fabric according to claim **4** wherein at least said upper MD yarns have an aspect ratio of at least 3:1.

6. A papermakers fabric according to claim **4** wherein said lower MD yarns are also 100% warp fill.

7. A papermakers fabric according to claim **4** wherein all of said MD yarns have an aspect ratio of at least 3:1 and total at least 200% warp fill.

8. A papermakers fabric according to claim 4 wherein said fabric consists essentially of all monofilament yarns.

9. A papermakers fabric according to claim 1 wherein said CMD yarn system further includes a middle layer of CMD yarns and wherein said MD yarns interweave with said middle layer CMD yarns with hidden interior knuckles.

10. A papermakers fabric according to claim 9 wherein said upper MD yarns repeat with respect to three of said upper layer CMD yarns with a float of two, and said lower MD yarns are woven in the inverse thereof.

11. A papermakers fabric according to claim 9 wherein said upper MD yarns repeat with respect to four of said upper layer CMD yarns with a float of two, and said lower MD yarns are woven in the inverse thereof.

12. A papermakers fabric according to claim 9 wherein said upper MD yarns repeat with respect to X of said upper layer CMD yarns with a float of Y, where Y is an integer greater than 1 and X is an integer not greater than 2Y, and said lower MD yarns are woven in the inverse thereof.

13. A papermakers fabric according to claim 9 wherein said upper MD yarns repeat with respect to X of said upper layer CMD yarns with a float of Y, where Y is an integer greater than 1 and X is an integer not greater than 2Y, and said lower MD yarns repeat with respect to Z of said lower layer CMD yarns, where Z is an integer which is an equal multiple of, or equally divisible by, X.

14. A papermakers fabric according to claim 13 wherein said lower MD yarns repeat with respect to Z of said lower layer CMD yarns with a float of W, where W is an integer greater than 1 and W is not less than half of Z.

15. A papermakers fabric according to claim 9 wherein at least said upper MD yarns have an aspect ratio of at least 3:1.

16. A papermakers fabric according to claim 9 wherein said lower MD yarns are also 100% warp fill.

17. A papermakers fabric according to claim 9 wherein all of said MD yarns have an aspect ratio of at least 3:1 and total at least 200% warp fill.

18. A papermakers fabric according to claim 9 wherein said fabric consists essentially of all monofilament yarns.

19. A papermakers fabric according to claim 1 wherein at least said upper MD yarns have an aspect ratio of at least 3:1.

20. A papermakers fabric according to claim 1 wherein said lower MD yarns are also 100% warp fill.

21. A papermakers fabric according to claim 1 wherein all of said MD yarns have an aspect ratio of at least 3:1 and total at least 200% warp fill.

22. A papermakers fabric according to claim 1 wherein said fabric consists essentially of all monofilament yarns.

23. A papermakers fabric comprising:

a single layer system of CMD yarns;

a system of flat monofilament MD yarns interwoven with said CMD yarns in a selected repeat pattern;

said MD yarn system having paired upper and lower yarns that are stacked in the same relative vertical alignment to each other throughout the body of the fabric; and

at least said upper MD yarns are 100% warp fill.

24. A papermakers fabric according to claim 23 wherein said upper MD yarns are interwoven with floats over a selected number of said CMD yarns such that the upper surface of the fabric is predominated by said upper MD yarn floats.

25. A papermakers fabric according to claim 24 wherein said MD yarns interweave with said CMD yarns with hidden knuckles.

26. A papermakers fabric according to claim 24 wherein said lower MD yarns are interwoven with said CMD yarns in an inverted image of the repeat of said upper MD yarns whereby the bottom surface of the fabric is also predominated by floats of said MD yarns.

27. A papermakers fabric according to claim 24 wherein said upper MD yarns repeat with respect to four of said upper layer CMD yarns with a float of three and said lower MD yarns are woven in the inverse thereof.

28. A papermakers fabric according to claim 27 wherein said MD yarns are interwoven with said CMD yarns in a balanced weave pattern such that said MD yarn system consists of two types of MD yarn pairs which are offset by two of said CMD yarns such that alternate CMD yarns are not woven in knuckles by said MD yarns and such that the CMD yarns which are woven in knuckles by said MD yarns are crimped by the weaving of said MD yarns.

29. A papermakers fabric according to claim 28 wherein said alternate CMD yarns which are not woven in knuckles by said MD yarns are larger than the CMD yarns which are woven in knuckles by said MD yarns.

30. A papermakers fabric according to claim 23 wherein said upper MD yarns repeat with respect to X of said CMD yarns with a float of Y, where Y is an integer greater than 1 and X is an integer not greater than 2Y, and said lower MD yarns are woven in the inverse thereof.

31. A papermakers fabric according to claim 23 wherein said upper MD yarns repeat with respect to X of said CMD yarns with a float of Y, where Y is an integer greater than 1 and X is an integer not greater than 2Y, and said lower MD yarns repeat with respect to Z of said CMD yarns, where Z is an integer which is an equal multiple of, or equally divisible by, X.

32. A papermakers fabric according to claim 31 wherein said lower MD yarns repeat with respect to Z of said CMD yarns with a float of W, where W is an integer greater than 1 and W is not less than half of Z.

33. A papermakers fabric according to claim 23 wherein at least said upper MD yarns have an aspect ratio of at least 3:1.

34. A papermakers fabric according to claim 23 wherein said lower MD yarns are also 100% warp fill.

35. A papermakers fabric according to claim 23 wherein all of said MD yarns have an aspect ratio of at least 3:1 and total at least 200% warp fill.

36. A papermakers fabric according to claim 23 wherein said fabric consists essentially of all monofilament yarns.

37. A papermakers fabric comprising:

a system of CMD yarns;

a system of flat monofilament MD yarns interwoven with said CMD yarns in a selected repeat pattern;

said MD yarn system having paired upper and lower yarns that are stacked in the same vertical alignment to each other throughout the body of the fabric; and

at least said upper MD yarns are 100% warp fill.

38. A papermakers fabric according to claim **37** wherein said upper MD yarns are interwoven with floats over a selected number of said CMD yarns such that the upper surface of the fabric is predominated by said upper MD yarn floats.

39. A papermakers fabric according to claim **38** wherein said MD yarns interweave with said CMD yarns with hidden knuckles.

40. A papermakers fabric according to claim **38** wherein said lower MD yarns are interwoven with said CMD yarns in an inverted image of the repeat of said upper MD yarns whereby the bottom surface of the fabric is also predominated by floats of said MD yarns.

41. A papermakers fabric according to claim **37** wherein said upper MD yarns repeat with respect to X of said CMD yarns with a float of Y, where Y is an integer greater than 1 and X is an integer not greater than 2Y, and said lower MD yarns are woven in the inverse thereof.

42. A papermakers fabric according to claim **37** wherein said upper MD yarns repeat with respect to X of said CMD yarns with a float of Y, where Y is an integer greater than 1 and X is an integer not greater than 2Y, and said lower MD yarns repeat with respect to Z of said CMD yarns, where Z is an integer which is an equal multiple of, or equally divisible by, X.

43. A papermakers fabric according to claim **42** wherein said lower MD yarns repeat with respect to Z of said CMD yarns with a float of W, where W is an integer greater than 1 and W is not less than half of Z.

44. A papermakers fabric according to claim **37** wherein at least said upper MD yarns have an aspect ratio of at least 3:1.

45. A papermakers fabric according to claim **37** wherein said lower MD yarns are also 100% warp fill.

46. A papermakers fabric according to claim **37** wherein all of said MD yarns have an aspect ratio of at least 3:1 and total at least 200% warp fill.

47. A papermakers fabric according to claim **37** wherein said fabric consists essentially of all monofilament yarns.

48. An industrial fabric comprising:

a system of CMD yarns;

a system of flat monofilament MD yarns interwoven with said CMD yarns in a selected repeat pattern;

said MD yarn system having paired upper and lower yarns that are stacked in the same vertical alignment to each other throughout the body of the fabric; and

at least said upper MD yarns are 100% warp fill.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 5,103,874

DATED : April 14, 1992 Page 1 of 2

INVENTOR(S) : Henry J. Lee

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below: On the title page : Item [56]

IN THE REFERENCES CITED

After "4,291,750 5/1990 Todd .....139/383 A X", insert --

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UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 5,103,874
DATED : April 14, 1992
INVENTOR(S) : Henry J. Lee

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

At column 3, line 45, after 'FIGS.' insert therefor --1,--; line 57, delete "yearn" and insert therefor --yarn--.

At column 5, line 25, after 'FIGS.' insert --1,--.

At column 8, line 52, delete ":".

At column 9, line 52, delete "&:o" and insert therefor --to--.

IN THE CLAIMS

In claim 37, column 12, line 66, after 'same' insert --relative--.

At claim 48, column 14, line 23, after 'same' insert --relative--.

Signed and Sealed this

Twenty-second Day of June, 1993

Attest:

Michael K. Kirk

MICHAEL K. KIRK

Attesting Officer

Acting Commissioner of Patents and Trademarks

[redacted]

Exhibit B

US005167261A

United States Patent [19]

Lee

[11] Patent Number: 5,167,261

[45] Date of Patent: Dec. 1, 1992

[54] **PAPERMAKERS FABRIC WITH STACKED MACHINE DIRECTION YARNS OF A HIGH WARP FILL**

[75] Inventor: **Henry J. Lee**, Summerville, S.C.

[73] Assignee: **Asten Group, Inc.**, Charleston, S.C.

[21] Appl. No.: **736,288**

[22] Filed: **Jul. 25, 1991**

Related U.S. Application Data

[63] Continuation of Ser. No. 534,164, Jun. 6, 1990.

[51] **Int. Cl.**[5] **D03D 13/00**

[52] **U.S. Cl.** ..... **139/383 A**

[58] **Field of Search** ..... 139/383 A, 425 A, 383 AA; 162/DIG. 1, 358

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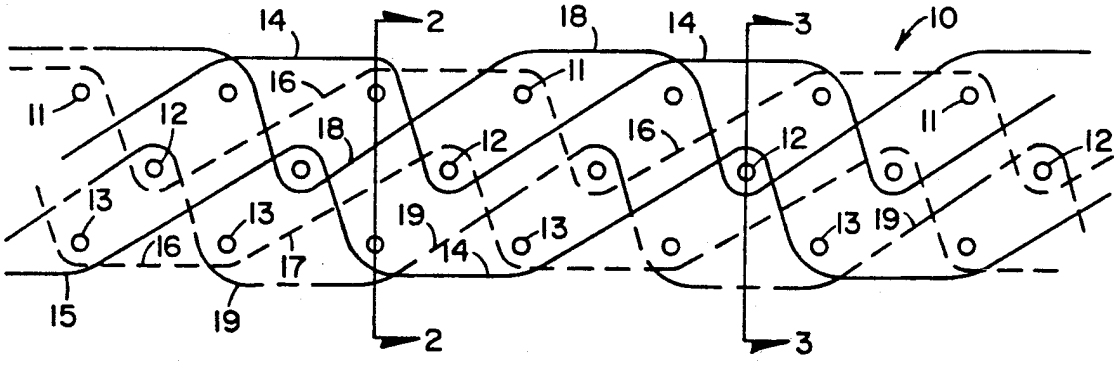
Primary Examiner—Andrew M. Falik

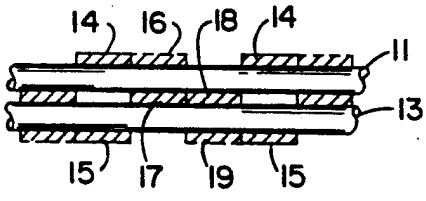
Attorney, Agent, or Firm—Volpe and Koenig

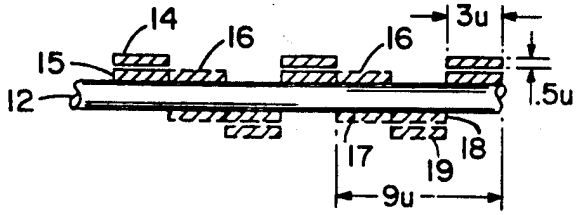
[57] **ABSTRACT**

A papermakers fabric have a system of flat monofilament machine direction yarns (hereinafter MD yarns). The system of MD yarns comprises upper and lower yarns which are vertically stacked. Preferably, the upper MD yarns define floats on the upper surface of the fabric and each upper MD yarn is paired in vertically stacked orientation with a lower MD yarn. At least the upper MD yarns are flat monofilament yarns woven contiguous with each other to define a warp fill of at least 80% to reduce the permeability of the fabric and to lock in the machine direction alignment of the stacking pairs of MD yarns. The stacked, contiguous woven machine direction system provides stability and permits the MD yarns to have a relatively high aspect ratio, cross-sectional width to height, of greater than 3:1. A seam for the fabric comprised of loops formed from selected flat MD yarns is provided to render the fabric endless during use in papermaking.

36 Claims, 3 Drawing Sheets







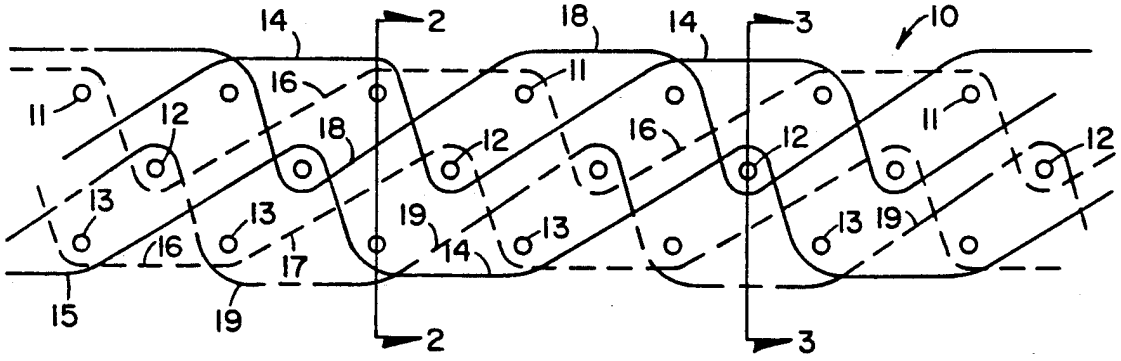


FIG. 1

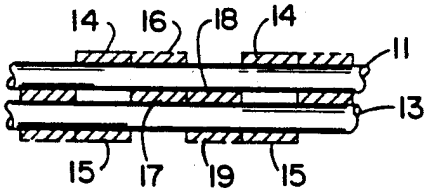


FIG. 2

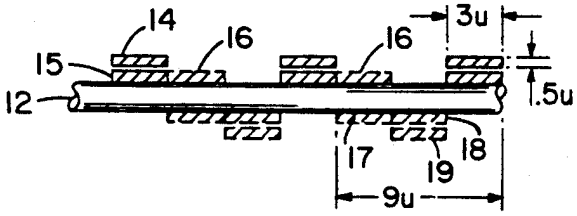


FIG. 3

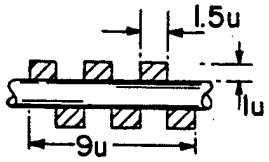


FIG. 4
PRIOR ART

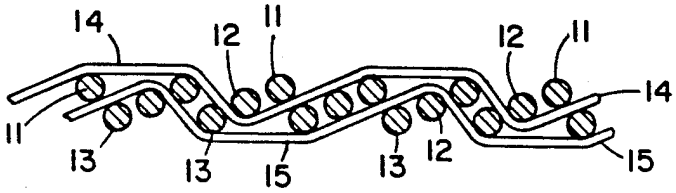


FIG. 5

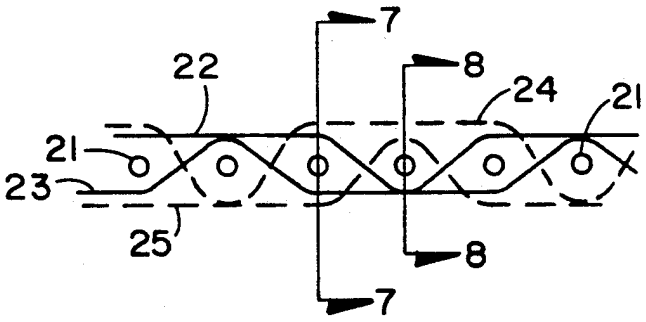


FIG. 6

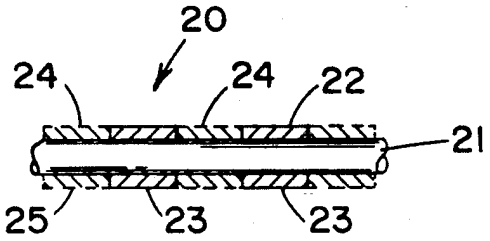


FIG. 7

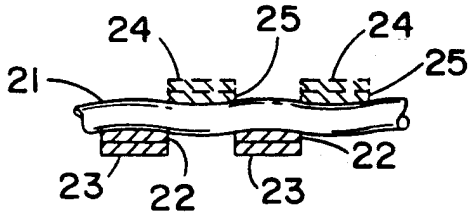


FIG. 8

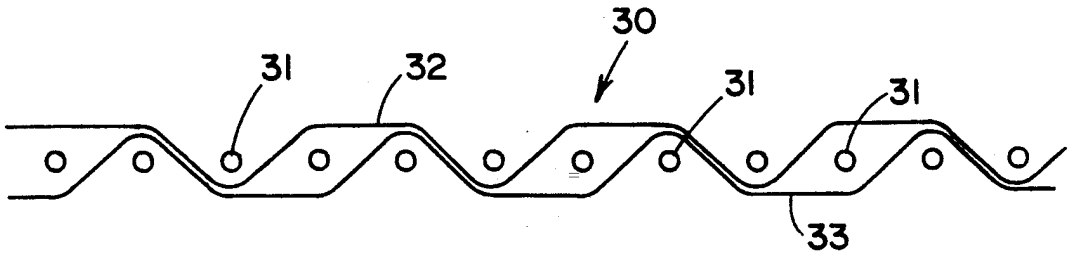


FIG. 9

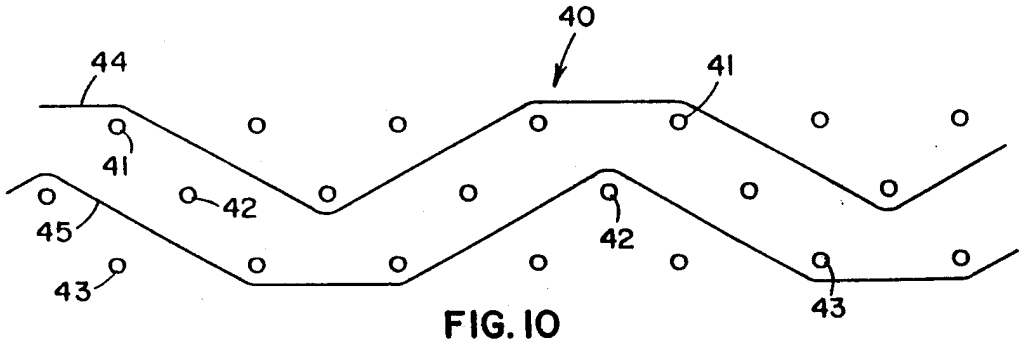


FIG. 10

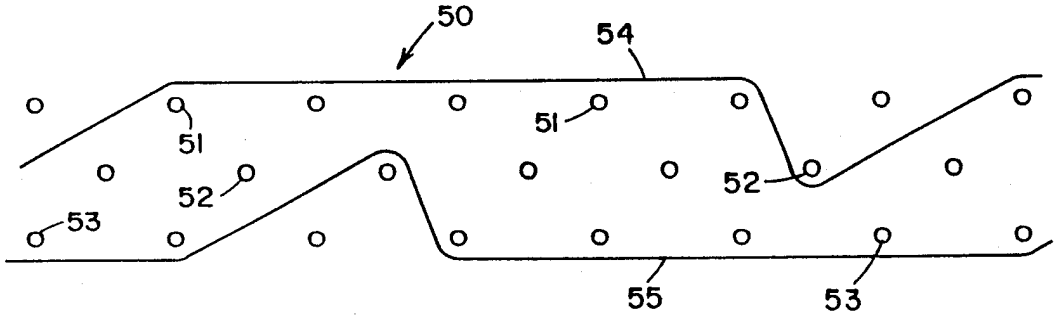


FIG. 11

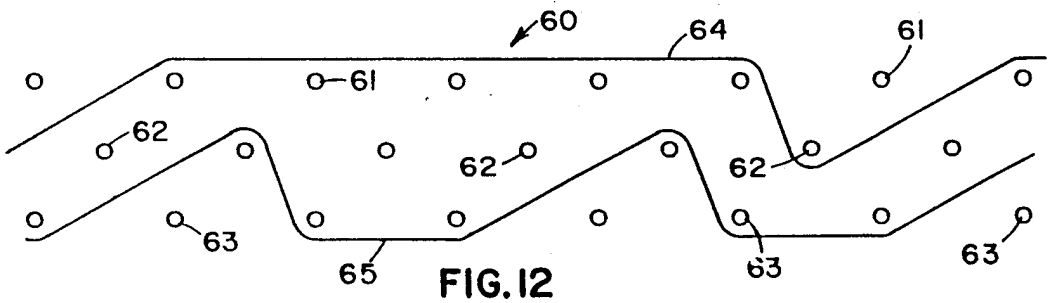


FIG. 12

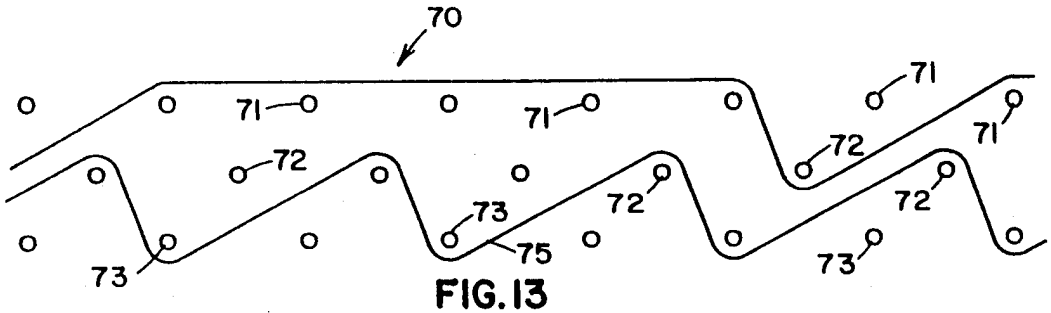


FIG. 13

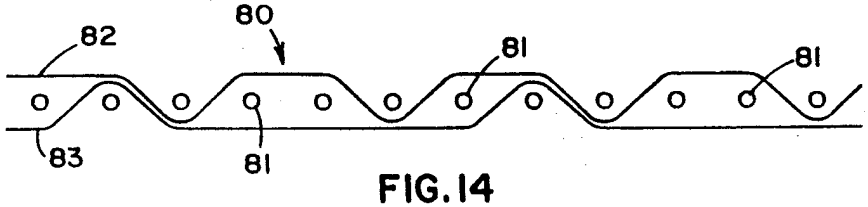


FIG. 14

PAPERMAKERS FABRIC WITH STACKED MACHINE DIRECTION YARNS OF A HIGH WARP FILL

This is a continuation of application Ser. No. 534,164, filed Jun. 6, 1990, allowed May 28, 1991.

The present invention relates to papermakers fabrics and in particular to fabrics comprised of flat monofilament yarns.

BACKGROUND OF THE INVENTION

Papermaking machines generally are comprised of three sections: forming, pressing, and drying. Papermakers fabrics are employed to transport a continuous paper sheet through the papermaking equipment as the paper is being manufactured. The requirements and desirable characteristics of papermakers fabrics vary in accordance with the particular section of the machine where the respective fabrics are utilized.

With the development of synthetic yarns, shaped monofilament yarns have been employed in the construction of papermakers fabrics. For example, U.S. Pat. No. 4,290,209 discloses a fabric woven of flat monofilament warp yarns; U.S. Pat. No. 4,755,420 discloses a non-woven construction where the papermakers fabric is comprised of spirals made from flat monofilament yarns.

Numerous weaves are known in the art which are employed to achieve different results. For example, U.S. Pat. No. 4,438,788 discloses a dryer fabric having three layers of cross machine direction yarns interwoven with a system of flat monofilament machine direction yarns such that floats are created on both the top and bottom surfaces of the fabric. The floats tend to provide a smooth surface for the fabric.

Permeability is an important criteria in the design of papermakers fabrics. In particular, with respect to fabrics made for running at high speeds on modern drying equipment, it is desirable to provide dryer fabrics with relatively low permeability.

U.S. Pat. No. 4,290,209 discloses the use of flat monofilament warp yarns woven contiguous with each other to provide a fabric with reduced permeability. However, even where flat warp yarns are woven contiguous with each other, additional means, such as stuffer yarns, are required to reduce the permeability of the fabric. As pointed out in that patent, it is desirable to avoid the use of fluffy, bulky stuffer yarns to reduce permeability which make the fabric susceptible to picking up foreign substances or retaining water.

U.S. Pat. No. 4,290,209 and U.S. Pat. No. 4,755,420 note practical limitations in the aspect ratio (cross-sectional width to height ratio) of machine direction warp yarns defining the structural weave of a fabric. The highest practical aspect ratio disclosed in those patents is 3:1, and the aspect ratio is preferably, less than 2:1.

U.S. Pat. No. 4,621,663, assigned to the assignee of the present invention, discloses one attempt to utilize high aspect ratio yarns (on the order of 5:1 and above) to define the surface of a papermakers dryer fabric. As disclosed in that patent, a woven base fabric is provided to support the high aspect ratio surface yarns. The woven base fabric is comprised of conventional round yarns and provides structural support and stability to the fabric disclosed in that patent.

U.S. Pat. No. 4,815,499 discloses the use of flat yarns in the context of a forming fabric. That patent discloses a composite fabric comprised of an upper fabric and a lower fabric tied together by binder yarns. The aspect ratio employed for the flat machine direction yarns in both the upper and lower fabrics are well under 3:1.

SUMMARY AND OBJECTS INVENTION

The present invention provides a papermakers fabric having a system of flat monofilament machine direction yarns (hereinafter MD yarns) which are stacked to control the permeability of the fabric. The present weave also provides for usage of high aspect ratio yarns as structural weave components. The system of MD yarns comprises upper and lower yarns which are vertically stacked. It is preferred that at least the upper MD yarns are woven with an actual warp count of at least 80%. Preferably, the upper MD yarns define floats on the upper surface of the fabric and each upper MD yarn is paired in a vertically stacked orientation with a lower MD yarn. The lower MD yarns may weave in an inverted image of the upper MD yarns to provide floats on the bottom fabric surface or may weave with a different repeat to provide a different surface on the bottom of the fabric.

At least the upper MD yarns are flat monofilament yarns woven contiguous with each other which results in a high warp fill to reduce the permeability of the fabric and to lock in the machine direction alignment of the stacking pairs of MD yarns. In the preferred embodiment, the same type and size yarns are used throughout the machine direction yarn system and both the top and the bottom MD yarns weave contiguously with adjacent top and bottom MD yarns, respectively. The stacked, contiguous woven machine direction system provides stability and permits the MD yarns to have a relatively high aspect ratio, cross-sectional width to height, of greater than 3:1.

It is an object of the invention to provide a papermakers fabrics having permeability controlled with woven flat machine direction yarns.

It is a further object of the invention to provide a low permeability fabric constructed of all monofilament yarns without the use of bulky stuffer yarns and without sacrificing strength or stability.

Other objects and advantages will become apparent from the following description of presently preferred embodiments.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is a schematic diagram of a papermakers fabric made in accordance with the teachings of the present invention;

FIG. **2** is a cross-sectional view of the fabric depicted in FIG. **1** along line **2—2**;

FIG. **3** is a cross-sectional view of the fabric depicted in FIG. **1** along line **3—3**;

FIG. **4** is a cross-sectional view of a prior art weave construction;

FIG. **5** illustrates the actual yarn structure of the fabric depicted in FIG. **1** in the finished fabric showing only two representative stacked MD yarns;

FIG. **6** is a schematic view of a second embodiment of a fabric made in accordance with the present invention;

FIG. **7** is a cross-sectional view of the fabric depicted in FIG. **6** along line **7—7**;

FIG. **8** is a cross-sectional view of the fabric depicted in FIG. **6** along line **8—8**;

FIG. 9 is a schematic view of a third alternate embodiment of a fabric made in accordance with the teachings of the present invention showing only one pair of stacked MD yarns;

FIG. 10 is a schematic view of a fourth alternate embodiment of a fabric made in accordance with the teachings of the present invention showing only one pair of stacked MD yarns;

FIG. 11 is a schematic view of a fifth alternate embodiment of a fabric made in accordance with the teachings of the present invention showing only one pair of stacked MD yarns;

FIG. 12 is a schematic view of a sixth alternate embodiment of a fabric made in accordance with the teachings of the present invention showing only one pair of stacked MD yarns;

FIG. 13 is a schematic view of a seventh alternate embodiment of a fabric made in accordance with the teachings of the present invention showing only one pair of stacked MD yarns; and

FIG. 14 is a schematic view of a eighth alternate embodiment of a fabric made in accordance with the teachings of the present invention showing only one pair of stacked MD yarns.

DETAILED DESCRIPTION OF PRESENTLY PREFERRED EMBODIMENTS

Referring to FIGS. 1, 2, and 3, there is shown a papermakers dryer fabric 10 comprising upper, middle and lower layers of cross machine direction (hereinafter CMD) yarns 11, 12, 13, respectively, interwoven with a system of MD yarns 14–19 which sequentially weave in a selected repeat pattern. The MD yarn system comprises upper MD yarns 14, 16, 18 which interweave with CMD yarns 11, 12 and lower MD yarns 15, 17, 19 which interweave with CMD yarns 12, 13.

The upper MD yarns 14, 16, 18 define floats on the top surface of the fabric 10 by weaving over two upper layer CMD yarns 11 dropping into the fabric to weave in an interior knuckle under one middle layer CMD yarn 12 and under one CMD yarn 11 and thereafter rising to the surface of the fabric to continue the repeat of the yarn. The floats over upper layer CMD yarns 11 of upper MD yarns 14, 16, 18 are staggered so that all of the upper and middle layer CMD yarns 11, 12 are maintained in the weave.

As will be recognized by those skilled in the art, the disclosed weave pattern with respect to FIGS. 1, 2, and 3, results in the top surface of the fabric having a twill pattern. Although the two-float twill pattern represented in FIGS. 1, 2, and 3 is a preferred embodiment, it will be recognized by those of ordinary skill in the art that the length of the float, the number of MD yarns in the repeat, and the ordering of the MD yarns may be selected as desired so that other patterns, twill or non-twill, are produced.

As best seen in FIGS. 2 and 3, lower MD yarns 15, 17, 19, weave directly beneath upper MD yarns 14, 16, 18, respectively, in a vertically stacked relationship. Accordingly, the upper and lower MD yarns are paired and weave throughout the body of the fabric with the same relative vertical stacked alignment. For example, with respect to yarn pair 14, 15, compare FIGS. 2 and 3 with FIGS. 1 and 5. As noted below, portions of the stacked yarns are preferably removed proximate the ends of the fabric to facilitate the creation of a seam.

It will be understood to those of ordinary skill in the art that upper and lower as used herein are relative terms defining the relationship of the yarns within the fabric. In use, papermakers fabrics travel a serpentine path and the orientation of any particular portion of a fabric changes accordingly as it follows that path. The lower yarns weave in an inverted image of their respective upper yarns. Each lower MD yarn 15, 17, 19 floats under two lower layer CMD yarns 13, rises into the fabric over one CMD yarn 13 and forms a knuckle around one middle layer CMD yarn 12 whereafter the yarn returns to the lower fabric surface to continue its repeat floating under the next two lower layer CMD yarns 13.

With respect to each pair of stacked yarns, the interior knuckle, formed around the middle layer CMD yarns 12 by one MD yarn, is hidden by the float of the other MD yarn. For example, in FIGS. 1 and 3, lower MD yarn 15 is depicted weaving a knuckle over CMD yarn 12 while MD yarn 14 is weaving its float over CMD yarns 11, thereby hiding the interior knuckle of lower MD yarn 15. Likewise, with respect to FIGS. 1 and 3, upper MD yarn 18 is depicted weaving a knuckle under yarn CMD yarn 12 while it is hidden by lower MD yarn 19 as it floats under CMD yarns 13.

The upper MD yarns 14, 16, 18, are woven contiguous with respect to each other. This maintains their respective parallel machine direction alignment and reduces permeability. Such close weaving of machine direction yarns is known in the art as 100% warp fill as explained in U.S. Pat. No. 4,290,209. As taught therein (and used herein), actual warp count in a woven fabric may vary between about 80%–125% in a single layer and still be considered 100% warp fill.

The crowding of MD yarns 14, 16, and 18 also serves to force MD yarns 15, 17, 19, into their stacked position beneath respective MD yarns 14, 16, 18. Preferably MD yarns 15, 17, and 19 are the same size as MD yarns 14, 16, and 18 so that they are likewise woven 100% warp fill. This results in the overall fabric of the preferred embodiment having 200% warp fill of MD yarns.

Since the lower MD yarns 15, 17, 19 are also preferably woven 100% warp fill, they likewise have the effect of maintaining the upper MD yarns 14, 16, 18 in stacked relationship with the respect to lower MD yarns 15, 17, 19. Accordingly, the respective MD yarn pairs 14 and 15, 16 and 17, 18 and 19 are doubly locked into position thereby enhancing the stability of the fabric.

As set forth in the U.S. Pat. No. 4,290,209, it has been recognized that machine direction flat yarns will weave in closer contact around cross machine direction yarns than round yarns. However, a 3:1 aspect ratio i.e. the ratio of cross-sectional width to height, was viewed as a practical limit for such woven yarns in order to preserve overall fabric stability. The present stacked MD yarn system preserves the stability and machine direction strength of the fabric and enables the usage of yarns with increased aspect ratio to more effectively control permeability.

The high aspect ratio of the MD yarns translates into reduced permeability. High aspect ratio yarns are wider and thinner than conventional flat yarns which have aspect ratios less than 3:1 and the same cross-sectional area. Equal cross-sectional area means that comparable yarns have substantially the same linear strength. The greater width of the high aspect ratio yarns translates into fewer interstices over the width of the fabric than with conventional yarns so that fewer openings exist in the fabric through which fluids may flow. The relative thinness of the high aspect ratio yarns enables the flat

MD yarns to more efficiently cradle, i.e. brace, the cross machine direction yarns to reduce the size of the interstices between machine direction and cross machine direction yarns.

For example, as illustrated in FIG. **4**, a fabric woven with a single layer system of a flat machine direction warp having a cross-sectional width of 1.5 units and a cross-sectional height of 1 unit, i.e. an aspect ratio of 1.5:1, is shown. Such fabric could be replaced by a fabric having the present dual stacked MD yarn system with MD yarns which are twice the width, i.e. 3 units, and half the height, i.e. 0.5 units. Such MD yarns thusly having a fourfold greater aspect ratio of 6:1, as illustrated in FIG. **3**.

The thinner, wider MD yarns more efficiently control permeability while the machine direction strength of the fabric remains essentially unaltered since the cross-sectional area of the MD yarns over the width of the fabric remains the same. For the above example, illustrated by FIGS. **4** and **3**, the conventional single MD yarn system fabric has six conventional contiguous flat yarns over 9 units of the fabric width having a cross-sectional area of 9 square units, i.e. 6*(lu.*1.5u.). The thinner, wider high aspect ratio yarns, woven as contiguous stacked MD yarns, define a fabric which has three stacked pairs of MD yarns over 9 units of fabric width. Thus such fabric also has a cross-sectional area of 9 square units, i.e. (3*(0.5u.*3u.))+(3*(0.5u.*3u.)), over 9 units of fabric width.

In one example, a fabric was woven in accordance with FIGS. **1**, **2** and **3**, wherein the CMD yarns **11**, **12**, **13** were polyester monofilament yarns 0.6 mm in diameter interwoven with MD yarns **14–19** which were flat polyester monofilament yarns having a width of 1.12 mm and a height of 0.2 mm. Accordingly, the aspect ratio of the flat MD yarns was 5.6:1. The fabric was woven at 48 warp ends per inch with a loom tension of 40 PLI (pounds per linear inch) and 12.5 CMD pick yarns per inch per layer (three layers).

The fabric was heat set in a conventional heat setting apparatus under conditions of temperature, tension and time within known ranges for polyester, monofilament yarns. For example, conventional polyester fabrics are heat set within parameters of 340° F.–380° F. temperature, 6–15 PLI (pounds per linear inch) tension, and 3–4 minutes time. However, due to their stable structure, the fabrics of the present invention are more tolerant to variations in heat setting parameters.

The fabric exhibited a warp modulus of 6000 PSI (pounds per square inch) measured by the ASTM D-1682-64 standard of the American Society for Testing and Materials. The fabric stretched less that 0.2% in length during heat setting. This result renders the manufacture of fabrics in accordance with the teachings of the present invention very reliable in achieving desired dimensional characteristic as compared to conventional fabrics.

The resultant heat set fabric had 12.5 CMD yarns per inch per layer with 106% MD warp fill with respect to both upper and lower MD yarns resulting in 212% actual warp fill for the fabric. The finished fabric has a permeability of 83CFM as measured by the ASTM D-737-75 standard.

As illustrated in FIG. **5**, when the fabric **10** is woven the three layers of CMD yarns **11**, **12**, **13** become compressed. This compression along with the relatively thin dimension of the MD yarns reduces the caliper of the fabric. Accordingly, the overall caliper of the fabric can be maintained relatively low and not significantly greater than conventional fabrics woven without stacked MD yarn pairs. In the above example, the caliper of the finished fabric was 0.050 inches.

It will be recognized by those of ordinary skill in the art that if either top MD yarns **14**, **16**, **18** or bottom MD yarns **15**, **17**, **19** are woven at 100% warp fill, the overall warp fill for the stacked fabric will be significantly greater than 100% which will contribute to the reduction of permeability of the fabric. The instant fabric having stacked MD yarns will be recognized as having a significantly greater percentage of a warp fill than fabrics which have an actual warp fill of 125% of non-stacked MD yarns brought about by crowding and lateral undulation of the warp strands. Although the 200% warp fill is preferred, a fabric may be woven having 100% fill for either the upper or lower MD yarns with a lesser degree of fill for the other MD yarns by utilizing yarns which are not as wide as those MD yarns woven at 100% warp fill. For example, upper yarns **14**, **16**, **18** could be 1 unit wide with lower layer yarns **15**, **17**, **19** being 0.75 units wide which would result in a fabric having approximately 175% warp fill.

Such variations can be used to achieve a selected degree of permeability. Alternatively, such variations could be employed to make a forming fabric. In such a case, the lower MD yarns would be woven 100% warp fill to define the machine side of the fabric and the upper MD yarns would be woven at a substantially lower percentage of fill to provide a more open paper forming surface.

Referring to FIGS. **6**, **7** and **8**, there is shown a second preferred embodiment of a fabric **20** made in accordance with the teachings of the present invention. Papermakers fabric **20** is comprised of a single layer of CMD yarns **21** interwoven with a system of stacked MD yarns **22–25** which weave in a selected repeat pattern. The MD yarn system comprises upper MD yarns **22**, **24** which define floats on the top surface of the fabric **20** by weaving over three CMD yarns **21**, dropping into the fabric to form a knuckle around the next one CMD yarn **21**, and thereafter continuing to float over the next three CMD yarns **21** in the repeat.

Lower MD yarns **23**, **25**, weave directly beneath respective upper MD yarns **22**, **24** in a vertically stacked relationship. The lower MD yarns weave in an inverted image of their respective upper MD yarns. Each lower MD yarn **23**, **25** floats under three CMD yarns **21**, weaves upwardly around the next one CMD yarn forming a knuckle and thereafter continues in the repeat to float under the next three CMD yarns **21**.

As can be seen with respect to FIGS. **6** and **8**, the knuckles formed by the lower MD yarns **23**, **25** are hidden by the floats defined by the upper MD yarns **22**, **24** respectively. Likewise the knuckles formed by the upper MD yarns **22**, **24** are hidden by the floats of the lower MD yarns **23**, **25** respectively.

The caliper of the fabric proximate the knuckle area shown in FIG. **8**, has a tendency to be somewhat greater than the caliper of the fabric at non-knuckle CMD yarns **21**, shown in FIG. **7**. However, the CMD yarns **21** around which the knuckles are formed become crimped which reduces the caliper of the fabric in that area as illustrated in FIG. **8**. Additionally, slightly larger size CMD yarns may be used for CMD yarns **21**, shown in FIG. **7**, which are not woven around as knuckles by the MD yarns.

A fabric was woven in accordance with FIGS. **6**, **7** and **8**, wherein the CMD yarns **21** were polyester monofilament yarns 0.7 mm in diameter interwoven with MD yarns **22–25** which were flat polyester monofilament yarns having a width of 1.12 mm and a height of 0.2 mm. Accordingly, the aspect ratio of the flat MD yarns was 5.6:1. The fabric was woven at 22 CMD pick yarns per inch. The fabric was heat set using conventional methods. The fabric exhibited a modulus of 6000 PSI. The fabric stretched less than 0.2% in length during heat setting. The resultant fabric had 22 CMD yarns per inch with 106% MD warp fill with respect to both upper and lower MD yarns resulting in 212% actual warp fill for the fabric. The finished fabric had a caliper of 0.048 inches and an air permeability of 60CFM.

The preferred inverted image weave of the lower MD yarns facilitates the creation of seaming loops at the end of the fabric which enable the fabric ends to be joined together. In forming a seaming loop, the upper MD yarns extend beyond the end of the fabric and the respective lower yarns are trimmed back a selected distance from the fabric end. The upper MD yarns are then bent back upon themselves and rewoven into the space vacated by the trimmed lower MD yarns. When the upper MD yarns are backwoven into the space previously occupied by the lower MD yarns, their crimp matches the pattern of the lower MD yarns, thereby locking the resultant end loops in position. Similarly, alternate top MD yarns can be backwoven tightly against the end of the fabric such that loops formed on the opposite end of the fabric can be intermeshed in the spaces provided by the non-loop forming MD yarns to seam the fabric via insertion of a pintle through the intermeshed end loops.

Since the top and bottom machine direction yarns are stacked, the resultant end loops are orthogonal to the plane of the fabric surface and do not have any twist. In conventional backweaving techniques, the loop defining yarns are normally backwoven into the fabric in a space adjacent to the yarn itself. Such conventional loop formation inherently imparts a twist to the seaming loop, see U.S. Pat. No. 4,438,788, FIG. **6**.

With reference to FIG. **9**, a third embodiment of a papermakers fabric **30** is shown. Fabric **30** comprises a single layer of CMD yarns **31** interwoven with stacked pairs of flat monofilament yarns in a selected repeat pattern. For clarity, only one pair of stacked MD yarns is shown comprising upper MD yarn **32** and lower MD yarn **33**. The upper MD yarns weave in a float over two CMD yarns **31**, form a single knuckle under the next CMD yarn **31** and thereafter repeat. Similarly the lower MD yarns weave in an inverted image of the upper MD yarns weaving under two CMD yarns **31**, forming a knuckle over the next CMD yarn **31** and then returning to the bottom surface of the fabric in the repeat. Since the repeat of both the upper and lower MD yarns is with respect to three CMD yarns **31**, a total of three different stacked pairs of yarns comprise the weave pattern of the MD yarn system.

A fabric was woven in accordance with FIG. **9** wherein the CMD yarns **31** were polyester monofilament yarns 0.7 mm in diameter interwoven with MD yarns which were flat polyester monofilament yarns having a width of 1.12 mm and a height of 0.2 mm. Accordingly, the aspect ratio of the flat MD yarns was 5.6:1. The fabric was woven **48** warp ends per inch under a loom tension of 60 PLI and 18 CMD pick yarns per inch. The fabric was heat set using conventional methods. The fabric exhibited a modulus of 6000 PSI. The fabric stretched less than 0.2% in length during heat setting. The resultant fabric had 18 CMD yarns per inch with 106% MD warp fill with respect to both upper and lower MD yarns resulting in 212% actual warp fill for the fabric. The finished fabric having a caliper of 0.046 inches and an air permeability of 66CFM.

With reference to FIG. **10**, a fourth embodiment of a papermakers fabric **40** is shown. Fabric **40** comprises upper, middle and lower layers of CMD yarns **41**, **42**, **43**, respectively, interwoven with stacked pairs of flat monofilament yarns in a selected repeat pattern. For clarity, only one pair of stacked MD yarns is shown comprising upper MD yarn **44** and lower MD yarn **45**. The upper MD yarns weave in a float over two upper layer CMD yarns **41**, under the next yarn **41** and a middle layer yarn **42** to form a single knuckle, under the next CMD yarn **41** and thereafter rise to the top surface to continue to repeat. Similarly, the lower MD yarns weave in an inverted image of the upper MD yarns weaving under two lower layer CMD yarns **43** over the next CMD yarn **43** and a middle CMD yarn **42** forming a knuckle, over the next CMD yarn **43** then returning to the bottom surface of the fabric to repeat. Since the repeat of both the upper and lower MD yarns is with respect to four upper and lower CMD yarns **41**, **43**, respectively, a total of four different stacked pairs of yarns comprise the weave pattern of the MD yarn system.

A fabric was woven in accordance with FIG. **10**, wherein the upper and lower layer CMD yarns **41**, **43** were nylon-sheathed, multifilament polyester yarns 0.62 mm in diameter and the middle layer CMD yarns **42** were polyester monofilament yarns 0.5 mm in diameter interwoven with MD yarns **22–25** which were flat polyester monofilament yarns having a width of 0.60 mm and a height of 0.38 mm. Accordingly, the aspect ratio of the flat MD yarns was 1.58:1. The fabric was woven with 96 warp ends per inch under a loom tension of 40 PLI and 15 CMD pick yarns per inch per layer. The fabric was heat set using conventional methods. The resultant fabric had 15 CMD yarns per inch per layer with 113% MD warp fill with respect to both upper and lower MD yarns resulting in 226% actual warp fill for the fabric. The finished fabric had a caliper of 0.075 inches and an air permeability of 60CFM.

FIGS. **11**, **12** and **13** illustrate the fifth, sixth and seventh embodiments of the present invention. FIG. **11** illustrates the weave of a relatively long float on both sides of the fabric; FIG. **12** illustrates how a stacked pair MD yarn weave can define floats of different lengths on opposite sides of the fabric; and FIG. **13** illustrates how a stacked pair MD yarn weave can be used to construct fabrics having MD knuckles on one side of the fabric.

Relatively long floats predominating the surfaces of a dryer fabric are beneficial for both the paper-carrying side as well as the machine side of the fabric. On the paper-carrying side, long floats provide greater contact area with the paper sheet for increased heat transfer. On the machine side, long floats provide increased wear surface and contact area to reduce bounce and flutter. The stacked pair MD yarn weave is versatile in allowing different surfaces to be defined on the top and bottom sides of the fabric. Accordingly, fabrics made in accordance with the teachings of the present invention may be used for other industrial purposes such as in the drying of sludge.

With respect to FIG. **11**, a fabric **50** is illustrated comprising three layers of yarns **51**, **52**, and **53** respectively. In this construction, the MD yarn pairs, such as the pair formed by upper layer yarn **54** and lower layer yarn **55**, define relatively long floats on both the top and bottom surfaces of the fabric. Upper yarn **54** weaves over five upper layer CMD yarns **51**, drops into the fabric to form a knuckle under one middle layer CMD yarn **52**, weaves under the next upper layer yarn **51** and thereafter repeats. Lower MD yarn **55** weaves in an inverted image under five lower layer CMD yarns **53**, rising into the fabric over the next CMD **53** to weave a knuckle over one middle layer CMD yarn **52** thereafter dropping to the bottom surface of the fabric to continue its repeat. In such a construction, six pairs of stacked MD yarns are utilized in the repeat of the fabric and are sequentially woven in a selected sequence to produce a desired pattern on the surfaces of the fabric which will be predominated by the MD yarn floats.

The embodiment shown in FIG. **12** depicts a fabric **60** in which the MD yarns weave with a five-float repeat on the top fabric surface and a two-float repeat on the bottom fabric surface. For example, upper MD yarn **64** interweaves with upper and middle CMD yarns **61**, **62** in the same manner that upper MD yarn **54** weaves with respective CMD yarns **51**, **52** with respect to fabric **50** in FIG. **11**. However, lower MD yarn **65**, which forms a stacked pair with upper MD yarn **64**, weaves in a two-float bottom repeat with respect lower and middle CMD yarns **63**, **62**. For example, lower MD yarn **65** floats under two lower layer CMD yarns **63**, rises above the next CMD yarn **63** to form a knuckle over one middle layer CMD yarn **62** and thereafter drops to the bottom surface of the fabric **60** to continue to repeat. As with the other embodiments discussed above, the interior knuckles formed by the lower MD yarns are hidden by the upper MD yarn of the respective stacked pair and vice-versa.

The construction shown in FIG. **12** permits different surfaces to be defined on the top and bottom of the fabric while utilizing the benefits of the stacked MD yarn pairing.

The embodiment shown in FIG. **13** discloses another example of a fabric **70** having five-float MD yarns predominating the upper surface of the fabric, but with MD knuckles on the lower surface of the fabric. This type of construction may be advantageously used to construct a forming fabric where the upper fabric surface, having relatively long floats, would be used as the machine side of the fabric and the knuckled lower surface of the fabric would be used as the paper forming side.

Fabric **70** includes three layers of CMD yarns **71**, **72**, **73** respectively which interweave with stacked pairs of MD yarns to define this construction. Only one pair of stacked pair of MD yarns **74**, **75** is depicted for clarity. Upper MD yarn **74** weaves in a five-float pattern with respect to upper and middle layer CMD yarns **71**, **72** in the same manner as upper MD yarn **54** with respect to fabric **50** shown in FIG. **11**. Lower MD yarn **75** weaves three interior knuckles and three lower surface knuckles with respect to middle and lower layer CMD yarns **72**, **73** under each upper surface float of its respective MD yarn pair yarn **74**. The repeat of the upper MD yarns is defined with respect to six upper layer CMD yarns **71** and the repeat of the lower MD yarns is defined with respect to only two lower layer CMD yarns **73**. Accordingly, there are six different pairs of stacked MD yarns which constitute the MD yarn system which, as noted above, can be arranged such that a desired pattern is formed on the upper surface of the fabric.

Generally for stacked pair weaves, the repeat of the upper MD yarns will be equally divisible by, or an equal multiple of, the repeat of the lower MD yarns in defining the stacking pair relationship. For example, with respect to FIG. **12** the repeat of the upper MD yarns is six upper layer CMD yarns which is equally divisible by the repeat of the lower MD yarns which is three lower layer CMD yarns.

With respect to the eighth alternate embodiment shown in FIG. **14**, a fabric **80** is illustrated having a single layer of CMD yarns **81** and a representative stacked pair of MD yarns **82**, **83**. Upper MD yarn **82** weaves with two floats over CMD yarns **81** with a repeat occurring with respect to three CMD yarns **81**. Lower MD yarn **83** weaves with five floats under CMD yarns **81** with a repeat of six CMD yarns **81**. Thus, in fabric **80**, the repeat of the upper MD yarns, which is three, is an equal multiple of the repeat of lower MD yarns, which is six.

With respect to single layer CMD fabrics made in accordance with the teachings of the present invention, in general, the upper MD yarns repeat with respect to X CMD yarns with a float of Y, where Y is an integer greater than 1 and X is an integer not greater than 2Y, and the lower MD yarns repeat with respect to Z CMD yarns with a float of W where Z is an integer which is an equal multiple of, or equally divisible by, X and W is an integer greater than 1 and is not less than half of Z.

A variety of other weave patterns employing the paired stacked weave construction of the instant invention may be constructed within the scope of the present invention. For example, in some applications it may be desirable to have MD yarn surface floats over six or more CMD yarns. Such fabrics are readily constructed in accordance with the teachings of the present invention.

What I claim is:

1. An industrial fabric having a system of CMD yarns and a system of flat monofilament MD yarns interwoven with said CMD yarns in a selected repeat pattern, wherein the MD yarn system is comprised of paired upper and lower yarns stacked in the same relative vertical alignment to each other throughout the body of the fabric and the actual warp fill of at least the upper MD yarns is at least 80%.

2. The fabric of claim **1** wherein the actual warp fill of the upper and lower MD yarns is at least 80%.

3. The fabric of claim **2** wherein the aspect ratio of at least the upper MD yarns is greater than 3:1.

4. The fabric of claim **2** wherein the aspect ratios of the upper and lower MD yarns are greater the 3:1.

5. The fabric of claim **1** wherein the actual warp fill of at least the upper MD yarns is no more than 125%.

6. The fabric of claim **5** wherein the aspect ratio of at least the upper MD yarns is greater than 3:1.

7. The fabric of claim **5** wherein the aspect ratios of the upper and lower MD yarns are greater than 3:1.

8. The fabric of claim **1** wherein the actual warp fill ratios of the upper and lower MD yarns are at least 80% but no more than 125%.

9. The fabric of claim **8** wherein the aspect ratio of at least the upper MD yarns is greater than 3:1.

10. The fabric of claim **8** wherein the aspect ratios of the upper and lower MD yarns are greater than 3:1.

11. The fabric of claim 1 wherein the aspect ratio of at least the upper MD yarns is greater than 3:1.

12. The fabric of claim 1 wherein the aspect ratios of the upper and lower MD yarns are greater than 3:1.

13. A papermakers fabric having a system of CMD yarns and a system of flat monofilament MD yarns interwoven with said CMD yarns in a selected repeat pattern, wherein the MD yarn system is comprised of paired upper and lower yarns stacked in the same relative vertical alignment to each other throughout the body of the fabric and the actual warp fill of at least the upper MD yarns is at least 80%.

14. The fabric of claim 13 wherein the actual warp fill of the upper and lower MD yarns is at least 80%.

15. The fabric of claim 14 wherein the aspect ratio of at least the upper MD yarns is greater than 3:1.

16. The fabric of claim 14 wherein the aspect ratios of the upper and lower MD yarns are greater than 3:1.

17. The fabric of claim 13 wherein the actual warp fill of at least the upper MD yarns is no more than 125%.

18. The fabric of claim 17 wherein the aspect ratio of at least the upper MD yarns is greater than 3:1.

19. The fabric of claim 17 wherein the aspect ratios of the upper and lower MD yarns are greater than 3:1.

20. The fabric of claim 13 wherein the actual warp fill ratios of the upper and lower MD yarns are at least 80% but no more than 125%.

21. The fabric of claim 20 wherein the aspect ratio of at least the upper MD yarns is greater than 3:1.

22. The fabric of claim 20 wherein the aspect ratios of the upper and lower MD yarns are greater than 3:1.

23. The fabric of claim 13 wherein the aspect ratio of at least the upper MD yarns is greater than 3:1.

24. The fabric of claim 13 wherein the aspect ratios of the upper and lower MD yarns are grater than 3:1.

25. A papermakers dryer fabric comprised of a system of CMD yarns and a system of flat monofilament MD yarns that includes upper and lower yarns; the systems are woven in a repeated pattern with upper and lower yarns of the MD yarn system stacked in the same relative vertical alignment to each other throughout the body of the fabric and the actual warp fill of at least the upper MD yarns is at least 80%.

26. The fabric of claim 25 wherein the actual warp fill of the upper and lower MD yarns is at least 80%.

27. The fabric of claim 26 wherein the aspect ratio of at least the upper MD yarns is greater than 3:1.

28. The fabric of claim 26 wherein the aspect ratios of the upper and lower MD yarns are greater than 3:1.

29. The fabric of claim 25 wherein the actual warp fill of at least the upper MD yarns is no more than 125%.

30. The fabric of claim 29 wherein the aspect ratio of at least the upper MD yarns is greater than 3:1.

31. The fabric of claim 29 wherein the aspect ratios of the upper and lower MD yarns are greater than 3:1.

32. The fabric of claim 25 wherein the actual warp fill ratios of the upper and lower MD yarns are at least 80% but no more than 125%.

33. The fabric of claim 32 wherein the aspect ratio of at least the upper MD yarns is greater than 3:1.

34. The fabric of claim 32 wherein the aspect ratios of the upper and lower MD yarns are greater than 3:1.

35. The fabric of claim 25 wherein the aspect ratio of at least the upper MD yarns is greater than 3:1.

36. The fabric of claim 25 wherein the aspect ratios of the upper and lower MD yarns are greater than 3:1.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 5,167,261
DATED : December 1, 1992
INVENTOR(S) : Henry J. Lee

It is certified that error appears in the above-indentified patent and that said Letters Patent is hereby corrected as shown below:

On the title page, under item [22], insert the following item:

--[*] The portion of the term of this patent subsequent to April 14, 2009, has been disclaimed.--.

In claim 4, column 10, line 55, delete the second occurrence of "the" and insert therefor --than--.

In claim 24, column 12, line 2, delete "grater" and insert therefor --greater--.

Signed and Sealed this

Twelfth Day of October, 1993

Attest:

BRUCE LEHMAN

Attesting Officer

Commissioner of Patents and Trademarks

Exhibit C

US005645112A

United States Patent [19]

Lee

[11] Patent Number: 5,645,112

[45] Date of Patent: Jul. 8, 1997

[54] **PAPERMAKERS FABRIC WITH ALTERNATING CRIMPED CMD YARNS**

[75] Inventor: **Henry J. Lee**, Summerville, S.C.

[73] Assignee: **Asten, Inc.**, Walterboro, S.C.,

[21] Appl. No.: **524,800**

[22] Filed: **Sep. 7, 1995**

Related U.S. Application Data

[63] Continuation of Ser. No. 288,158, Aug. 10, 1994, Pat. No. 5,449,026, which is a continuation of Ser. No. 43,016, Apr. 5, 1993, abandoned, which is a continuation of Ser. No. 855,904, Apr. 13, 1992, Pat. No. 5,199,467, which is a continuation of Ser. No. 534,164, Jun. 6, 1990, Pat. No. 5,103,874.

[51] **Int. Cl.**[6] **D03D 13/00**; D03D 15/00

[52] **U.S. Cl.** ..... **139/383 A**

[58] **Field of Search** ..... 139/383 A

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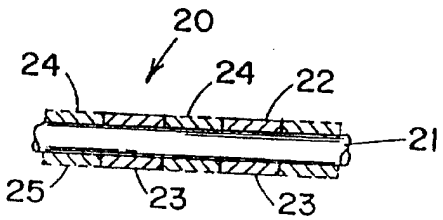
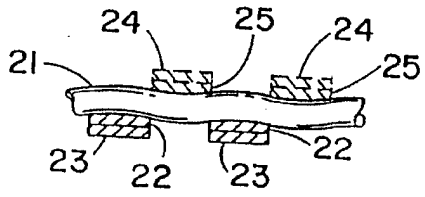
Primary Examiner—Andy Falik
Attorney, Agent, or Firm—Volpe and Koenig, P.C.

[57] **ABSTRACT**

A papermakers fabric having a system of flat monofilament yarns interwoven in a balanced weave pattern with preferably the flat yarns being machine direction yarns woven in stacked pairs with a single layer of cross machine direction yarns. The preferred weave pattern is selected such that the machine direction yarns impart crimp to alternate cross machine direction yarns by selectively weaving floats over multiple adjacent CMD yarns and knuckles under single CMD yarns. The invention provides for the use of flat yarns having an aspect ratio greater than 3:1.

30 Claims, 3 Drawing Sheets





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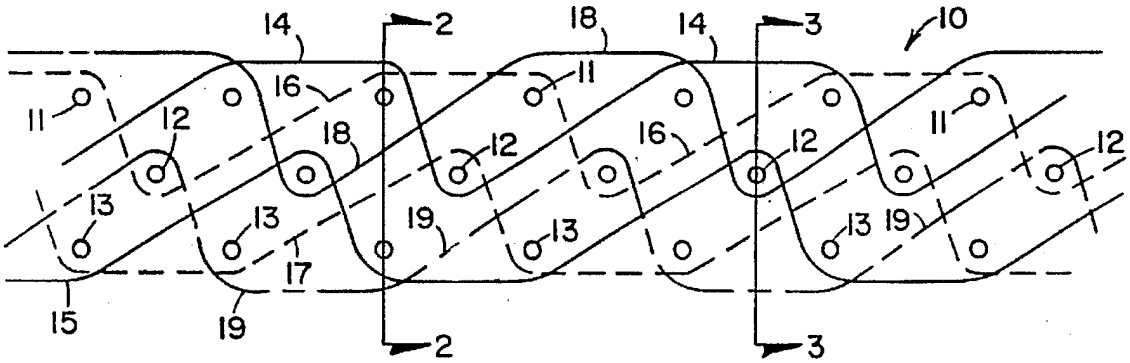

FIG. 1

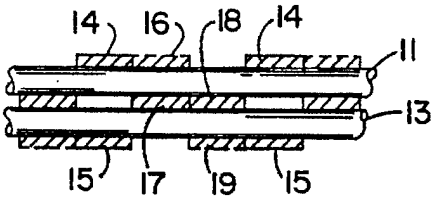

FIG. 2

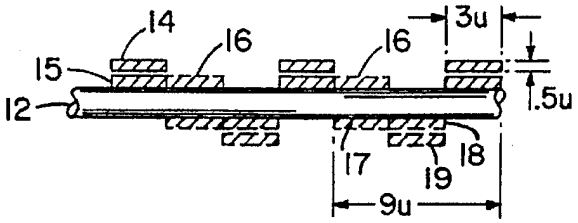

FIG. 3

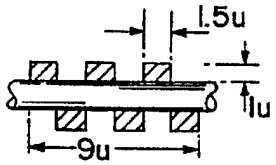

FIG. 4
PRIOR ART

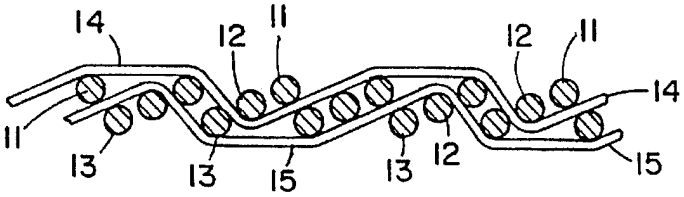

FIG. 5

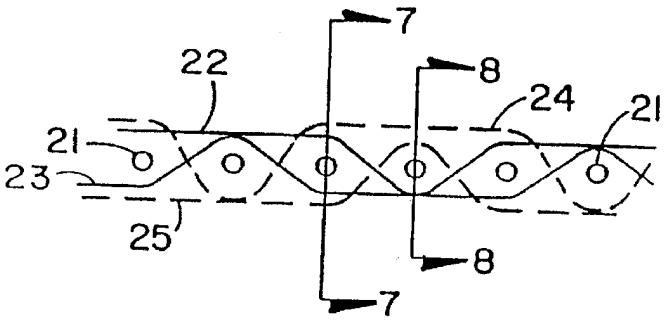

FIG. 6

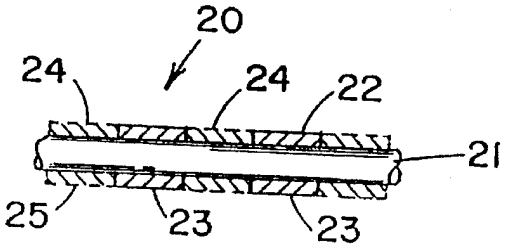

FIG. 7

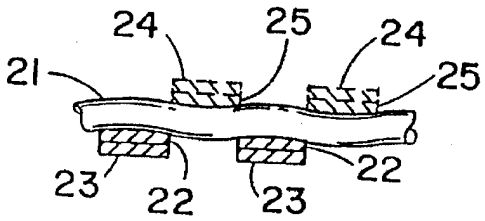

FIG. 8

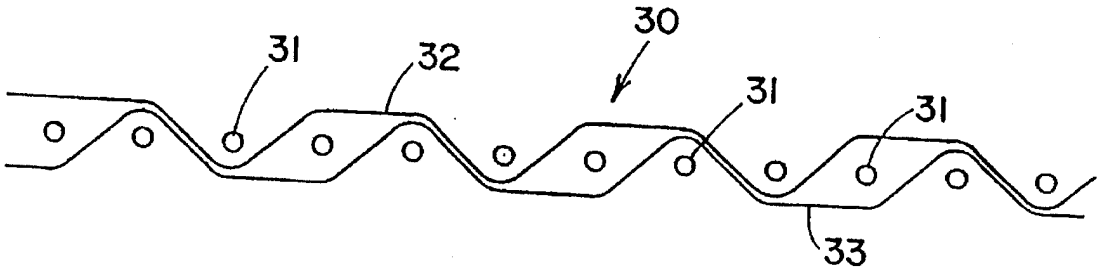

FIG. 9

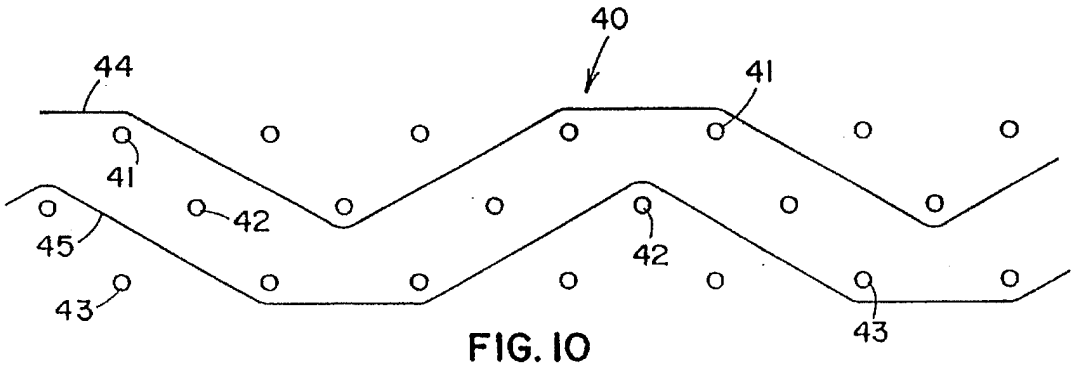

FIG. 10

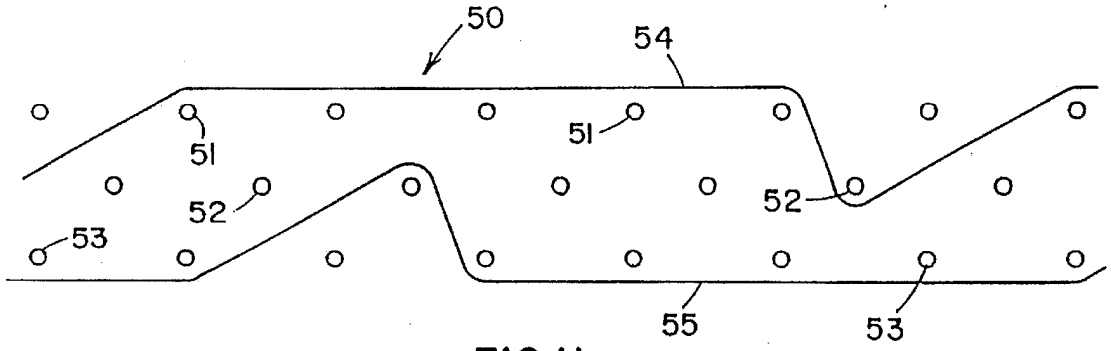

FIG. 11

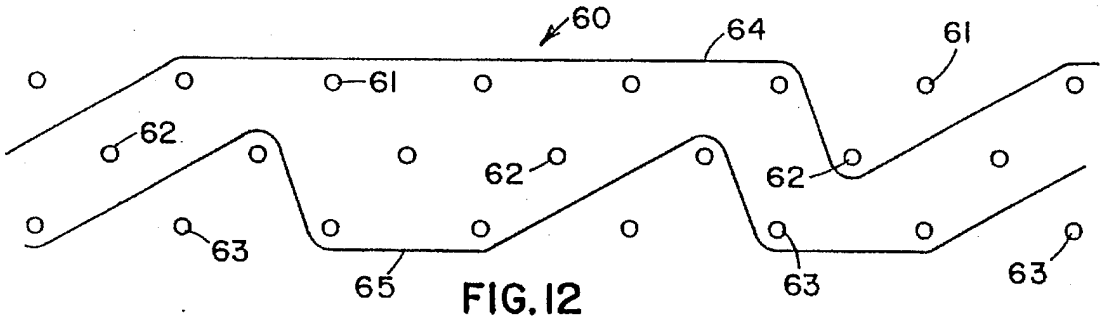

FIG. 12

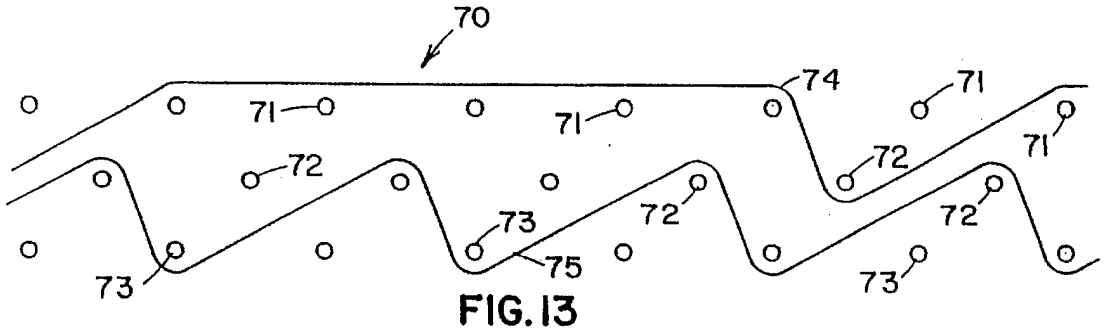

FIG. 13

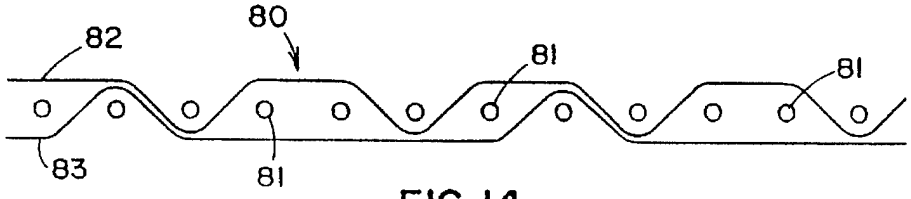

FIG. 14

PAPERMAKERS FABRIC WITH ALTERNATING CRIMPED CMD YARNS

This is a continuation of application Ser. No. 08/288,158, filed on Aug. 10, 1994, now U.S. Pat. No. 5,449,026, which in turn is a file wrapper continuation of application Ser. No. 08/043,016 filed Apr. 5, 1993, which is a continuation of application Ser. No. 07/855,904, filed on Apr. 13, 1992, now U.S. Pat. No. 5,199,467, which in turn is a continuation of application Ser. No. 07/534,164 filed Jun. 6, 1990, now U.S. Pat. No. 5,103,874.

The present invention relates to papermakers fabrics and in particular to fabrics comprised of flat monofilament yarns

BACKGROUND OF THE INVENTION

Papermaking machines generally are comprised of three sections: forming, pressing, and drying. Papermakers fabrics are employed to transport a continuous paper sheet through the papermaking equipment as the paper is being manufactured. The requirements and desirable characteristics of papermakers fabrics vary in accordance with the particular section of the machine where the respective fabrics are utilized.

With the development of synthetic yarns, shaped monofilament yarns have been employed in the construction of papermakers fabrics. For example, U.S. Pat. No. 4,290,209 discloses a fabric woven of flat monofilament warp yarns; U.S. Pat. No. 4,755,420 discloses a non-woven construction where the papermakers fabric is comprised of spirals made from flat monofilament yarns.

Numerous weaves are known in the art which are employed to achieve different results. For example, U.S. Pat. No. 4,438,788 discloses a dryer fabric having three layers of cross machine direction yarns interwoven with a system of flat monofilament machine direction yarns such that floats are created on both the top and bottom surfaces of the fabric. The floats tend to provide a smooth surface for the fabric.

Permeability is an important criteria in the design of papermakers fabrics. In particular, with respect to fabrics made for running at high speeds on modern drying equipment, it is desirable to provide dryer fabrics with relatively low permeability.

U.S. Pat. No. 4,290,209 discloses the use of flat monofilament warp yarns woven contiguous with each other to provide a fabric with reduced permeability. However, even where flat warp yarns are woven contiguous with each other, additional means, such as stuffer yarns, are required to reduce the permeability of the fabric. As pointed out in that patent, it is desirable to avoid the use of fluffy, bulky stuffer yarns to reduce permeability which make the fabric susceptible to picking up foreign substances or retaining water.

U.S. Pat. No. 4,290,209 and U.S. Pat. No. 4,755,420 note practical limitations in the aspect ratio (cross-sectional width to height ratio) of machine direction warp yarns defining the structural weave of a fabric. The highest practical aspect ratio disclosed in those patents is 3:1, and the aspect ratio is preferably, less than 2:1.

U.S. Pat. No. 4,621,663, assigned to the assignee of the present invention, discloses one attempt to utilize high aspect ratio yarns (on the order of 5:1 and above) to define the surface of a papermakers dryer fabric. As disclosed in that patent, a woven base fabric is provided to support the high aspect ratio surface yarns. The woven base fabric is comprised of conventional round yarns and provides structural support and stability to the fabric disclosed in that patent.

U.S. Pat. No. 4,815,499 discloses the use of flat yarns in the context of a forming fabric. That patent discloses a composite fabric comprised of an upper fabric and a lower fabric tied together by binder yarns. The aspect ratio employed for the flat machine direction yarns in both the upper and lower fabrics are well under 3:1.

SUMMARY AND OBJECTS INVENTION

The present invention provides a papermakers fabric having a system of flat monofilament machine direction yarns (hereinafter MD yarns) which are stacked to control the permeability of the fabric. The present weave also provides for usage of big high aspect ratio yarns as structural weave components. The system of MD yarns comprises upper and lower yarns which are vertically stacked. Preferably, the upper MD yarns define floats on the upper surface of the fabric and each upper MD yarn is paired in a vertically stacked orientation with a lower MD yarn. The lower MD yarns may weave in an inverted image of the upper MD yarns to provide floats on the bottom fabric surface or may weave with a different repeat to provide a different surface on the bottom of the fabric.

At least the upper MD yarns are flat monofilament yarns woven contiguous with each other to reduce the permeability of the fabric and to lock in the machine direction alignment of the stacking pairs of MD yarns. In the preferred embodiment, the same type and size yarns are used throughout the machine direction yarn system and both the top and the bottom MD yarns weave contiguously with adjacent top and bottom MD yarns, respectively. The stacked, contiguous woven machine direction system provides stability and permits the MD yarns to have a relatively high aspect ratio, cross-sectional width to height, of greater than 3:1.

It is an object of the invention to provide a papermakers fabrics having permeability controlled with woven flat machine direction yarns.

It is a further object of the invention to provide a low permeability fabric constructed of all monofilament yarns without the use of bulky stuffer yarns and without sacrificing strength or stability.

Other objects and advantages will become apparent from the following description of presently preferred embodiments.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is a schematic diagram of a papermakers fabric made in accordance with the teachings of the present invention;

FIG. **2** is a cross-sectional view of the fabric depicted in FIG. **1** along line **2—2**;

FIG. **3** is a cross-sectional view of the fabric depicted in FIG. **1** along line **3—3**;

FIG. **4** is a cross-sectional view of a prior art weave construction;

FIG. **5** illustrates the actual yarn structure of the fabric depicted in FIG. **1** in the finished fabric showing only two representative stacked MD yarns;

FIG. **6** is a schematic view of a second embodiment of a fabric made in accordance with the present invention;

FIG. **7** is a cross-sectional view of the fabric depicted in FIG. **6** along line **7—7**;

FIG. **8** is a cross-sectional view of the fabric depicted in FIG. **6** along line **8—8**;

FIG. **9** is a schematic view of a third alternate embodiment of a fabric made in accordance with the teachings of the present invention showing only one pair of stacked MD yarns;

FIG. **10** is a schematic view of a fourth alternate embodiment of a fabric made in accordance with the teachings of the present invention showing only one pair of stacked MD yarns;

FIG. **11** is a schematic view of a fifth alternate embodiment of a fabric made in accordance with the teachings of the present invention showing only one pair of stacked MD yarns;

FIG. **12** is a schematic view of a sixth alternate embodiment of a fabric made in accordance with the teachings of the present invention showing only one pair of stacked MD yarns;

FIG. **13** is a schematic view of a seventh alternate embodiment of a fabric made in accordance with the teachings of the present invention showing only one pair of stacked MD yarns; and

FIG. **14** is a schematic view of a eighth alternate embodiment of a fabric made in accordance with the teachings of the present invention showing only one pair of stacked MD yarns.

DETAILED DESCRIPTION OF PRESENTLY PREFERRED EMBODIMENTS

Referring to FIGS. **1**, **2**, and **3**, there is shown a papermakers dryer fabric **10** comprising upper,. middle and lower layers of cross machine direction (hereinafter CMD) yarns **11**, **12**, **13**, respectively, interwoven with a system of MD yarns **14–19** which sequentially weave in a selected repeat pattern. The MD yarn system comprises upper MD yarns **14**, **16**, **18** which interweave with CMD yarns **11**, **12** and lower MD yarns **15**, **17**, **19** which interweave with CMD yarns **12**, **13**.

The upper MD yarns **14**, **16**, **18** define floats on the top surface of the fabric **10** by weaving over two upper layer CMD yarns **11** dropping into the fabric to weave in an interior knuckle under one middle layer CMD yarn **12** and under one CMD yarn **11** and thereafter rising to the surface of the fabric to continue the repeat of the yarn. The floats over upper layer CMD yarns **11** of upper MD yarns **14**, **16**, **18** are staggered so that all of the upper and middle layer CMD yarns **11**, **12** are maintained in the weave.

As will be recognized by those skilled in the art, the disclosed weave pattern with respect to FIGS. **1**, **2**, and **3**, results in the top surface of the fabric having a twill pattern. Although the two-float twill pattern represented in FIGS. **1**, **2**, and **3** is a preferred embodiment, it will be recognized by those of ordinary skill in the art that the length of the float, the number of MD yarns in the repeat, and the ordering of the MD yarns may be selected as desired so that other patterns, twill or non-twill, are produced.

As best seen in FIGS. **2** and **3**, lower MD yarns **15**, **17**, **19**, weave directly beneath upper MD yarns **14**, **16**, **18**, respectively, in a vertically stacked relationship. The lower yarns weave in an inverted image of their respective upper yarns. Each lower MD yarn **15**, **17**, **19** floats under two lower layer CMD yarns **13**, rises into the fabric over one CMD yarn **13** and forms a knuckle around one middle layer CMD yarn **12** whereafter the yarn returns to the lower fabric surface to continue its repeat floating under the next two lower layer CMD yarns **13**.

With respect to each pair of stacked yarns, the interior knuckle, formed around the middle layer CMD yarns **12** by one MD yarn, is hidden by the float of the other MD yarn. For example, in FIGS. **1** and **3**, lower MD yarn **15** is depicted weaving a knuckle over CMD yarn **12** while MD yarn **14** is weaving its float over CMD yarns **11**, thereby hiding the interior knuckle of lower MD yarn **15**. Likewise, with respect to FIGS. **1** and **3**, upper MD yarn **18** is depicted weaving a knuckle under yarn CMD yarn **12** while it is hidden by lower MD yarn **19** as it floats under CMD yarns **13**.

The upper MD yarns **14**, **16**, **18**, are woven contiguous with respect to each other. This maintains their respective parallel machine direction alignment and reduces permeability. Such close weaving of machine direction yarns is known in the art as 100% warp fill as explained in U.S. Pat. No. 4,290,209. As taught therein (and used herein), actual warp fill in a woven fabric may vary between about 80%–125% in a single layer and still be considered 100% warp fill.

The crowding of MD yarns **14**, **16**, and **18** also serves to force MD yarns **15**, **17**, **19**, into their stacked position beneath respective MD yarns **14**, **16**, **18**. Preferably MD yarns **15**, **17**, and **19** are the same size as MD yarns **14**, **16**, and **18** so that they are likewise woven 100% warp fill. This results in the overall fabric of the preferred embodiment having 200% warp fill of MD yarns.

Since the lower MD yarns **15**, **17**, **19** are also preferably woven 100% warp fill, they likewise have the effect of maintaining the upper MD yarns **14**, **16**, **18** in stacked relationship with the respect to lower MD yarns **15**, **17**, **19**. Accordingly, the respective MD yarn pairs **14** and **15**, **16** and **17**, **18** and **19** are doubly locked into position thereby enhancing the stability of the fabric.

As set forth in the U.S. Pat. No. 4,290,209, it has been recognized that machine direction flat yarns will weave in closer contact around cross machine direction yarns than round yarns. However, a 3:1 aspect ratio was viewed as a practical limit for such woven yarns in order to preserve overall fabric stability. The present stacked MD yarn system preserves the stability and machine direction strength of the fabric and enables the usage of yarns with increased aspect ratio to more effectively control permeability.

The high aspect ratio of the MD yarns translates into reduced permeability. High aspect ratio yarns are wider and thinner than conventional flat yarns which have aspect ratios less than 3:1 and the same cross-sectional area. Equal cross-sectional area means that comparable yarns have substantially the same linear strength. The greater width of the high aspect ratio yarns translates into fewer interstices over the width of the fabric than with conventional yarns so that fewer openings exist in the fabric through which fluids may flow. The relative thinness of the high aspect ratio yarns enables the flat MD yarns to more efficiently cradle, i.e. brace, the cross machine direction yarns to reduce the size of the interstices between machine direction and cross machine direction yarns.

For example, as illustrated in FIG. **4**, a fabric woven with a single layer system of a flat machine direction warp having a cross-sectional width of 1.5 units and a cross-sectional height of 1 unit, i.e. an aspect ratio of 1.5:1, is shown. Such fabric could be replaced by a fabric having the present dual stacked MD yarn system with MD yarns which are twice the width, i.e. 3 units, and half the height, i.e. 0.5 units. Such MD yarns thusly having a fourfold greater aspect ratio of 6:1, as illustrated in FIG. **3**.

The thinner, wider MD yarns more efficiently control permeability while the machine direction strength of the fabric remains essentially unaltered since the cross-sectional area of the MD yarns over the width of the fabric remains the same. For the above example, illustrated by FIGS. **4** and **3**,

the conventional single MD yarn system fabric has six conventional contiguous flat yarns over 9 units of the fabric width having a cross-sectional area of 9 square units, i.e. 6*(1 u.*1.5 u.). The thinner, wider high aspect ratio yarns, woven as contiguous stacked MD yarns, define a fabric which has three stacked pairs of MD yarns over 9 units of fabric width. Thus such fabric also has a cross-sectional area of 9 square units, i.e. (3*(0.5 u.*3 u.))+(3*(0.5 u.*3 u.)), over 9 units of fabric width.

In one example, a fabric was woven in accordance with FIGS. **1**, **2** and **3**, wherein the CMD yarns **11**, **12**, **13** were polyester monofilament yarns 0.6 mm in diameter interwoven with MD yarns **14–19** which were flat polyester monofilament yarns having a width of 1.12 mm and a height of 0.2 mm. Accordingly, the aspect ratio of the flat MD yarns was 5.6:1. The fabric was woven at 48 warp ends per inch with a loom tension of 40 PLI (pounds per linear inch) and 12.5 CMD pick yarns per inch per layer (three layers).

The fabric was heat set in a conventional heat setting apparatus under conditions of temperature, tension and time within known ranges for polyester monofilament yarns. For example, conventional polyester 6/5/60 fabrics are heat set within parameters of 340° F.–380° F. temperature, 6–15 PLI (pounds per linear inch) tension, and 3–4 minutes time. However, due to their stable structure, the fabrics of the present invention are more tolerant to variations in heat setting parameters.

The fabric exhibited a warp modulus of 6000 PSI (pounds per square inch) measured by the ASTM D-1682-64 standard of the American Society for Testing and Materials. The fabric stretched less that 0.2% in length during heat setting. This result renders the manufacture of fabrics in accordance with the teachings of the present invention very reliable in achieving desired dimensional characteristic as compared to conventional fabrics.

The resultant heat set fabric had 12.5 CMD yarns per inch per layer with 106% MD warp fill with respect to both upper and lower MD yarns resulting in 212% actual warp fill for the fabric. The finished fabric has a permeability of 83 CFM as measured by the ASTM D-737-75 standard.

As illustrated in FIG. **5**, when the fabric **10** is woven the three layers of CMD yarns **11**. **12**. **13** become compressed. This compression along with the relatively thin dimension of the MD yarns reduces the caliper of the fabric. Accordingly, the overall caliper of the fabric can be maintained relatively low and not significantly greater than conventional fabrics woven without stacked MD yarn pairs in the above example, the caliper of the finished fabric was 0.050 inches.

It will be recognized by those of ordinary skill in the art that if either top MD yarns **14**. **16**. **18** or bottom MD yarns **15**, **17**, **19** are woven at 100% warp fill. the overall warp fill for the stacked fabric will be significantly greater than 100% which will contribute to the reduction of permeability of the fabric. The instant fabric having stacked MD yarns will be recognized as having a significantly greater percentage of a warp fill than fabrics which have an actual warp fill of 125% of non-stacked MD yarns brought about by crowding and lateral undulation of the warp strands. Although the 200% warp fill is preferred, a fabric may be woven having 100% fill for either the upper or lower MD yarns with a lesser degree of fill for the other MD yarns by utilizing yarns which are not as wide as those MD yarns woven at 100% warp fill. For example, upper yarns **14**, **16**, **18** could be 1 unit wide with lower layer yarns **15**, **17**, **19** being 0.75 units wide which would result in a fabric having approximately 175% warp fill.

Such variations can be used to achieve a selected degree of permeability. Alternatively, such variations could be employed to make a forming fabric in such a case, the lower MD yarns would be woven 100% warp fill to define the machine side of the fabric and the upper MD yarns would be woven at a substantially lower percentage of fill to provide a more open paper forming surface.

Referring to FIGS. **6**, **7** and **8**, there is shown a second preferred embodiment of a fabric **20** made in accordance with the teachings of the present invention. Papermakers fabric **20** is comprised of a single layer of CMD yarns **21** interwoven with a system of stacked MD yarns **22–25** which weave in a selected repeat pattern. The MD yarn system comprises upper MD yarns **22**, **24** which define floats on the top surface of the fabric **20** by weaving over three CMD yarns **21**, dropping into the fabric to form a knuckle around the next one CMD yarn **21**, and thereafter continuing to float over the next three CMD yarns **21** in the repeat. Although repeating with respect to four CMD yarns, as illustrated, there are only two types of yarns in the upper MD yarn repeat as represented by MD yarns **22**, **24**.

Lower MD yarns **23**, **25**, weave directly beneath respective upper MD yarns **22**, **24** in a vertically stacked relationship. The lower MD yarns weave in an inverted image of their respective upper MD yarns. Each lower MD yarn **23**, **25** floats under three CMD yarns **21**, weaves upwardly around the next one CMD yarn forming a knuckle and thereafter continues in the repeat to float under the next three CMD yarns **21**.

As can be seen with respect to FIGS. **6** and **8**, the knuckles formed by the lower MD yarns **23**, **25** are hidden by the floats defined by the upper MD yarns **22**, **24** respectively. Likewise the knuckles formed by the upper MD yarns **22**, **24** are hidden by the floats of the lower MD yarns **23**, **25** respectively.

The caliper of the fabric proximate the knuckle area shown in FIG. **8**, has a tendency to be somewhat greater than the caliper of the fabric at non-knuckle CMD yarns **21**, shown in FIG. **7**. However, the CMD yarns **21** around which the knuckles are formed become crimped which reduces the caliper of the fabric in that area as illustrated in FIG. **8**. Additionally, slightly larger size CMD yarns may be used for CMD yarns **21**, shown in FIG. **7**, which are not woven around as knuckles by the MD yarns.

A fabric was woven in accordance with FIGS. **6**, **7** and **8**, wherein the CMD yarns **21** were polyester monofilament yarns 0.7 mm in diameter interwoven with MD yarns **22–25** which were flat polyester monofilament yarns having a width of 1.12 mm and a height of 0.2 mm. Accordingly, the aspect ratio of the flat MD yarns was 5.6:1. The fabric was woven at 22 CMD pick yarns per inch. The fabric was heat set using conventional methods. The fabric exhibited a modulus of 6000 PSI. The fabric stretched less than 0.2% in length during heat setting. The resultant fabric had 22 CMD yarns per inch with 106% MD warp fill with respect to both upper and lower MD yarns resulting in 212% actual warp fill for the fabric. The finished fabric had a caliper of 0.048 inches and an air permeability of 60 CFM.

The preferred inverted image weave of the lower MD yarns facilitates the creation of seaming loops at the end of the fabric which enable the fabric ends to be joined together. In forming a seaming loop, the upper MD yarns extend beyond the end of the fabric and the respective lower yarns are trimmed back a selected distance from the fabric end. The upper MD yarns are then bent back upon themselves and rewoven into the space vacated by the trimmed lower

MD yarns. When the upper MD yarns are backwoven into the space previously occupied by the lower MD yarns, their crimp matches the pattern of the lower MD yarns, thereby locking the resultant end loops in position. Similarly, alternate top MD yarns can be backwoven tightly against the end of the fabric such that loops formed on the opposite end of the fabric can be intermeshed in the spaces provided by the non-loop forming MD yarns to seam the fabric via insertion of a pintle through the intermeshed end loops.

Since the top and bottom machine direction yarns are stacked, the resultant end loops are orthogonal to the plane of the fabric surface and do not have any twist. In conventional backweaving techniques, the loop defining yarns are normally backwoven into the fabric in a space adjacent to the yarn itself. Such conventional loop formation inherently imparts a twist to the seaming loop, see U.S. Pat. No. 4,438,788, FIG. 6.

With reference to FIG. **9**, a third embodiment of a papermakers fabric **30** is shown. Fabric **30** comprises a single layer of CMD yarns **31** interwoven with stacked pairs of flat monofilament yarns in a selected repeat pattern. For clarity, only one pair of stacked MD yarns is shown comprising upper MD yarn **32** and lower MD yarn **33**. The upper MD yarns weave in a float over two CMD yarns **31**, form a single knuckle under the next CMD yarn **31** and thereafter repeat. Similarly the lower MD yarns weave in an inverted image of the upper MD yarns weaving under two CMD yarns **31**, forming a knuckle over the next CMD yarn **31** and then returning to the bottom surface of the fabric in the repeat. Since the repeat of both the upper and lower MD yarns is with respect to three CMD yarns **31**, a total of three different stacked pairs of yarns comprise the weave pattern of the MD yarn system.

A fabric was woven in accordance with FIG. **9** wherein the CMD yarns **31** were polyester monofilament yarns 0.7 mm in diameter interwoven with MD yarns which were flat polyester monofilament yarns having a width of 1.12 mm and a height of 0.2 mm. Accordingly, the aspect ratio of the flat MD yarns was 5.6:1. The fabric was woven 48 warp ends per inch under a loom tension of 60 PLI and 18 CMD pick yarns per inch. The fabric was heat set using conventional methods. The fabric exhibited a modulus of 6000 PSI. The fabric stretched less than 0.2% in length during heat setting. The resultant fabric had 18 CMD yarns per inch with 106% MD warp fill with respect to both upper and lower MD yarns resulting in 212% actual warp fill for the fabric. The finished fabric having a caliper of 0.046 inches and an air permeability of 66 CFM.

With reference to FIG. **10**, a fourth embodiment of a papermakers fabric **40** is shown. Fabric **40** comprises upper, middle and lower layers of CMD yarns **41**, **42**, **43**, respectively, interwoven with stacked pairs of flat monofilament yarns in a selected repeat pattern. For clarity, only one pair of stacked MD yarns is shown comprising upper MD yarn **44** and lower MD yarn **45**. The upper MD yarns weave in a float over two upper layer CMD yarns **41**, under the next yarn **41** and a middle layer yarn **42** to form a single knuckle, under the next CMD yarn **41** and thereafter rise to the top surface to continue to repeat. Similarly, the lower MD yarns weave in an inverted image of the upper MD yarns weaving under two lower layer CMD yarns **43** over the next CMD yarn **43** and a middle CMD yarn **42** forming a knuckle, over the next CMD yarn **43** then returning to the bottom surface of the fabric to repeat. Since the repeat of both the upper and lower MD yarns is with respect to four upper and lower CMD yarns **41**, **43**, respectively, a total of four different stacked pairs of yarns comprise the weave pattern of the MD yarn system.

A fabric was woven in accordance with FIG. **10**, wherein the upper and lower layer CMD yarns **41**, **43** were nylon-sheathed, multifilament polyester yarns 0.62 mm in diameter and the middle layer CMD yarns **42** were polyester monofilament yarns 0.5 mm in diameter interwoven with MD yarns **22–25** which were flat polyester monofilament yarns having a width of 0.60 mm and a height of 0.38 mm. Accordingly, the aspect ratio of the flat MD yarns was 1.58:1. The fabric was woven with 96 warp ends per inch under a loom tension of 40 PLI and 15 CMD pick yarns per inch per layer. The fabric was heat set using conventional methods. The resultant fabric had 15 CMD yarns per inch per layer with 113% MD warp fill with respect to both upper and lower MD yarns resulting in 226% actual warp fill for the fabric. The finished fabric had a caliper of 0.075 inches and an air permeability of 60 CFM.

FIGS. **11**, **12** and **13** illustrate the fifth, sixth and seventh embodiments of the present invention. FIG. **11** illustrates the weave of a relatively long float on both sides of the fabric; FIG. **12** illustrates how a stacked pair MD yarn weave can define floats of different lengths on opposite sides of the fabric; and FIG. **13** illustrates how a stacked pair MD yarn weave can be used to construct fabrics having MD knuckles on one side of the fabric.

Relatively long floats predominating the surfaces of a dryer fabric are beneficial for both the paper-carrying (or forming or sheet support) side as well as the machine (or roller contact) side of the fabric. On the paper-carrying side, long floats provide greater contact area with the paper sheet for increased heat transfer. On the machine side, long floats provide increased wear surface and contact area to reduce bounce and flutter. The stacked pair MD yarn weave is versatile in allowing different surfaces to be defined on the top and bottom sides of the fabric. Accordingly, fabrics made in accordance with the teachings of the present invention may be used for other industrial purposes such as in the drying of sludge.

With respect to FIG. **11**, a fabric **50** is illustrated comprising three layers of yarns **51**, **52**, and **53** respectively. In this construction, the MD yarn pairs, such as the pair formed by upper layer yarn **54** and lower layer yarn **55**, define relatively long floats on both the top and bottom surfaces of the fabric. Upper yarn **54** weaves over five upper layer CMD yarns **51**, drops into the fabric to form a knuckle under one middle layer CMD yarn **52**, weaves under the next upper layer yarn **51** and thereafter repeats. Lower MD yarn **55** weaves in an inverted image under five lower layer CMD yarns **53**, rising into the fabric over the next CMD **53** to weave a knuckle over one middle layer CMD yarn **52** thereafter dropping to the bottom surface of the fabric to continue its repeat. In such a construction six pairs of stacked MD yarns are utilized in the repeat of the fabric and are sequentially woven in a selected sequence to produce a desired pattern on the surfaces of the fabric which will be predominated by the MD yarn floats.

The embodiment shown in FIG. **12** depicts a fabric **60** in which the MD yarns weave with a five-float repeat on the top fabric surface and a two-float repeat on the bottom fabric surface. For example, upper MD yarn **64** interweaves with upper and middle CMD yarns **61**, **62** in the same manner that upper MD yarn **54** weaves with respective CMD yarns **51**, **52** with respect to fabric **50** in FIG. **11**. However, lower MD yarn **65**, which forms a stacked pair with upper MD yarn **64**, weaves in a two-float bottom repeat with respect lower and middle CMD yarns **63**, **62**. For example, lower MD yarn **65** floats under two lower layer CMD yarns **63**, rises above the next CMD yarn **63** to form a knuckle over one middle layer

CMD yarn **62** and thereafter drops to the bottom surface of the fabric **60** to continue to repeat. As with the other embodiments discussed above, the interior knuckles formed by the lower MD yarns are hidden by the upper MD yarn of the respective stacked pair and vice-versa.

The construction shown in FIG. **12** permits different surfaces to be defined on the top and bottom of the fabric while utilizing the benefits of the stacked MD yarn pairing.

The embodiment shown in FIG. **13** discloses another example of a fabric **70** having five-float MD yarns predominating the upper surface of the fabric, but with MD knuckles on the lower surface of the fabric. This type of construction may be advantageously used to construct a forming fabric where the upper fabric surface, having relatively long floats, would be used as the machine side of the fabric and the knuckled lower surface of the fabric would be used as the paper forming side.

Fabric **70** includes three layers of CMD yarns **71, 72, 73** respectively which interweave with stacked pairs of MD yarns to define this construction. Only one pair of stacked pair of MD yarns **74, 75** is depicted for clarity. Upper MD yarn **74** weaves in a five-float pattern with respect to upper and middle layer CMD yarns **71, 72** in the same manner as upper MD yarn **54** with respect to fabric **50** shown in FIG. **11**. Lower MD yarn **75** weaves three interior knuckles and three lower surface knuckles with respect to middle and lower layer CMD yarns **72, 73** under each upper surface float of its respective MD yarn pair yarn **74**. The repeat of the upper MD yarns is defined with respect to six upper layer CMD yarns **71** and the repeat of the lower MD yarns is defined with respect to only two lower layer CMD yarns **73**. Accordingly, there are six different pairs of stacked MD yarns which constitute the MD yarn system which, as noted above, can be arranged such that a desired pattern is formed on the upper surface of the fabric.

Generally for stacked pair weaves, the repeat of the upper MD yarns will be equally divisible by, or an equal multiple of, the repeat of the lower MD yarns in defining the stacking pair relationship. For example, with respect to FIG. **12** the repeat of the upper MD yarns is six upper layer CMD yarns which is equally divisible by the repeat of the lower MD yarns which is three lower layer CMD yarns.

With respect to the eighth alternate embodiment shown in FIG. **14**, a fabric **80** is illustrated having a single layer of CMD yarns **81** and a representative stacked pair of MD yarns **82, 83**. Upper MD yarn **82** weaves with two floats over CMD yarns **81** with a repeat occurring with respect to three CMD yarns **81**. Lower MD yarn **83** weaves with five floats under CMD yarns **81** with a repeat of six CMD yarns **81**. Thus, in fabric **80**, the repeat of the upper MD yarns, which is three, is an equal multiple of the repeat of lower MD yarns, which is six.

A variety of other weave patterns employing the paired stacked weave construction of the instant invention may be constructed within the scope of the present invention. For example, in some applications it may be desirable to have MD yarn surface floats over six or more CMD yarns. Such fabrics are readily constructed in accordance with the teachings of the present invention.

What I claim is:

1. A woven papermakers fabric having top and bottom sides comprising:

a single layer of first system yarns;

a second system of yarns including at least a first subsystem of yarns interwoven with said layer of first system yarns in a selected repeat pattern; and

said first subsystem yarns of said second system repeating with respect to four yarns of said single layer of first system yarns with a float over three of said single layer of first system yarns and woven in a balanced weave pattern where said first subsystem yarns consist of a repeat of only two types of alternating adjacent yarns, the first type floating over every first, second and third first system yarns and weaving under every fourth yarn in each repeat, the second type floating over every third, fourth and first first system yarns and weaving under every second first system yarn in each repeat such that said first subsystem yarns impart crimp to every said second and fourth first system yarn in each repeat, whereby said subsystem of second system yarns define floats on the top side of the fabric.

2. A woven papermakers fabric according to claim **1** wherein:

said second system of yarns includes a second subsystem of yarns interwoven with said single layer of first system yarns in a selected repeat pattern; and

said second subsystem yarns repeating with respect to four yarns of said single layer of first system yarns with a float under three of said single layer of first system yarns and woven in a balance weave pattern where said second subsystem yarns consist of two types of alternating adjacent yarns, the first type floating under every first, second and third first system yarns and weaving over every fourth first system yarn in each repeat, the second type floating under every third, fourth and first first system yarns and weaving over every second first system yarn in each repeat such that said second subsystem yarns impart crimp to the same first system yarns which are crimped by said first subsystem yarns, whereby said second subsystem of second system yarns define floats on the bottom side of the fabric.

3. A woven papermakers fabric according to claim **2** wherein said first system yarns are round cross machine direction yarns and said second system yarns are flat monofilament machine direction yarns.

4. An industrial fabric comprising a single layer of CMD yarns interwoven with a system of MD yarns, characterized in that alternate CMD yarns are crimped to a significantly greater degree than the respective adjacent other CMD yarns in said single CMD layer by at least some of said MD yarns weaving knuckles around each said alternate CMD yarns and all of said MD yarns weaving in floats either over or under said other CMD yarns.

5. A fabric according to claim **4** wherein said:

MD yarns are flat monofilament yarns having paired upper and lower yarns stacked in vertical alignment; and

at least said upper MD yarns are woven with an actual warp fill in the range of 80%–125%.

6. A fabric according to claim **4** wherein CMD yarns alternate between a first relatively larger diameter and a second relatively smaller diameter in said single CMD layer.

7. A fabric according to claim **4** wherein said CMD yarns are flat monofilament yarns having an aspect ratio greater than 3:1.

8. A fabric according to claim **4** wherein said CMD yarns include yarns of at least two different diameters and are interwoven in a selected repeat pattern such that the CMD yarns having the relatively smaller diameter are crimped significantly more than the CMD yarns having the relatively larger diameter.

9. A fabric according to claim **8** wherein said:

MD yarns are flat monofilament yarns having paired upper and lower yarns stacked in vertical alignment; and

at least said upper MD yarns are woven with an actual warp fill in the range of 80%–125%.

10. A fabric according to claim **8** wherein the CMD yarns alternate between a first relatively larger diameter and a second relatively smaller diameter in said single CMD layer.

11. A fabric according to claim **8** wherein said CMD yarns are flat monofilament yarns having an aspect ratio greater than 3:1.

12. A fabric according to claim **4** wherein said MD yarns repeat with respect to four of said CMD yarns with a float of three such that first and third CMD yarns within the float are not the CMD yarns which have the significantly greater degree of crimp.

13. A fabric according to claim **12** wherein said CMD yarns are flat monofilament yarns having an aspect ratio greater than 3:1.

14. A fabric according to claim **4** wherein the float of some of said MD yarns is over three CMD yarns and the float of other of said MD yarns is under three CMD yarns within a fabric repeat.

15. A fabric according to claim **14** wherein said CMD yarns are flat monofilament yarns having an aspect ratio greater than 3:1.

16. A fabric according to claim **4** wherein each of the MD yarns which have floats under the CMD yarns are disposed beneath at least one MD yarn which has its float weaving over the CMD yarns.

17. A fabric according to claim **16** wherein said CMD yarns include yarns of at least two different diameters and are flat monofilament yarns having an aspect ratio greater than 3:1.

18. A woven papermakers fabric having top and bottom sides comprising:

a single layer of cross machine direction yarns;

a system of machine direction yarns including at least a first subsystem of yarns interwoven with said layer of cross machine direction yarns in a selected repeat pattern; and

said first subsystem of yarns repeating with respect to four yarns of said single layer of cross machine direction with a float over three of said single layer of cross machine direction and woven in a balanced weave pattern where said first subsystem yarns consist of a repeat of only two types of alternating adjacent yarns, the first type floating over every first, second and third cross machine direction yarns and weaving under every fourth cross machine direction yarn in each repeat, the second type floating over third, fourth and first cross machine direction yarns and weaving under every second cross machine direction yarn in each repeat such that said first subsystem machine direction yarns impart crimp to every said second and fourth cross machine direction yarn in each repeat, whereby said first subsystem machine direction yarns define floats on the top side of the fabric.

19. A woven papermakers fabric according to claim **18** wherein:

said system of machine direction yarns includes a second subsystem of yarns interwoven with said single layer of cross machine direction yarns in a selected repeat pattern; and

said second subsystem of yarns repeating with respect to four yarns of said single layer of cross machine direction yarns with a float under three of said single layer of cross machine direction yarns and woven in a balanced weave pattern where said second subsystem yarns consist of a repeat of two types of alternating adjacent yarns, the first type floating under every first, second and third cross machine direction yarns and weaving over every fourth cross machine direction yarn in each repeat, the second type floating under every third, fourth and first cross machine direction yarns and weaving over every second cross machine direction yarn in each repeat such that said second subsystem machine direction yarns impart crimp to every said second and fourth cross machine direction yarn in each repeat, whereby said second subsystem machine direction yarns define floats on the bottom side of the fabric.

20. A woven papermakers fabric according to claim **19** wherein said cross machine direction yarns are round yarns; said machine direction yarns are flat yarns; and said first subsystem machine direction yarns are stacked in vertical alignment with respect to said second subsystem machine direction yarns.

21. A woven papermakers fabric comprising a system of CMD (cross-machine direction) yarns interwoven with a system of MD (machine direction) yarns in a balanced repeat pattern wherein said fabric comprises at least a first layer of MD yarns interwoven in a selected repeat pattern with at least a first layer of said CMD yarns wherein the selected repeat pattern of said first layer of MD yarns includes a repeat of only first and second flat monofilament MD yarns; said first flat first layer MD yarn floating over every first, second and third CMD yarns of said first CMD layer and weaving under every fourth yarn of said first CMD layer in each repeat; and said second flat first layer MD yarns floating over every third, fourth and first CMD yarns of said first CMD layer and weaving under every second yarn of said first CMD layer in each repeat such that said first layer of MD yarns impart crimp to said second and fourth first layer CMD yarns, but do not impart crimp to said first and third first layer CMD yarns.

22. A papermakers fabric according to claim **21** wherein said first and second flat first layer MD yarns have an aspect ratio greater than 3:1.

23. A papermakers fabric according to claim **21** wherein said first layer CMD yarns are round and alternate between a first diameter and a second diameter different from said first diameter.

24. A papermakers fabric according to claim **21** wherein the selected repeat pattern of said first layer MD yarns consists of said first and second flat MD yarns.

25. A papermakers fabric according to claim **21** wherein said MD yarn system includes a second layer of MD yarns interwoven with said system of CMD yarns in a balance repeat pattern including at least one flat monofilament second layer MD yarn woven in stacked vertical alignment beneath each of said first and second flat monofilament first layer MD yarns.

26. A papermakers fabric according to claim **25** wherein the repeat pattern of said second layer MD yarns includes only first and second flat monofilament second layer MD yarns; said first flat second layer MD yarn floating under every first, second and third CMD yarns of a CMD yarn layer and weaving over every fourth CMD yarn of a CMD yarn layer in each repeat; and said second flat second layer MD yarn floating under every third, fourth and first CMD yarn of a layer of CMD yarns and weaving over every second CMD yarn of a layer of CMD yarns.

27. A papermakers fabric according to claim **26** wherein said CMD yarn system consists of said first layer of CMD yarns and both said first layer and second layer flat monofilament MD yarns weave with said first layer CMD yarns.

28. A papermakers fabric according to claim 26 wherein said first and second flat second layer MD yarns have an aspect ratio greater than 3:1.

29. A papermakers fabric according to claim 26 wherein said CMD yarns are all round and have the same diameter.

30. A papermakers fabric according to claim 26 wherein the repeat pattern of said first layer MD yarns consists of said first and second flat MD yarns.

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UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 5,645,112
DATED : July 8, 1997
INVENTOR(S) : Henry J. Lee

It is certified that error appears in the above-indentified patent and that said Letters Patent is hereby corrected as shown below:

At column 2, line 12, delete the word "big".

At column 5, line 22, delete "6/5/60".

At column 5, line 48, delete "pairs in" and insert therefor --pairs. In--.

Signed and Sealed this

Twenty-eighth Day of October, 1997

Attest:

BRUCE LEHMAN

Attesting Officer

Commissioner of Patents and Trademarks