United States Patent [19]

Dow

[11] **3,874,422**

[45] **Apr. 1, 1975**

[54] **TRIAXIALLY WOVEN FABRICS OF UNIFORM COMPLIANCY AND POROSITY**

[75] Inventor: **Norris F. Dow**, Radnor, Pa.

[73] Assignee: **N.F. Doweave, Inc.**, Philadelphia, Pa.

[22] Filed: **Mar. 13, 1974**

[21] Appl. No.: **450,735**

[52] **U.S. Cl.**..... **139/383 R**, 139/419, 139/DIG. 1

[51] **Int. Cl.**..... **D03d 13/00**

[58] **Field of Search**..... 139/DIG. 1, 11, 383 R, 139/28, 419, 424

[56] **References Cited**

UNITED STATES PATENTS

912,950	2/1909	Gibert	139/DIG. 1
1,057,477	4/1913	Brindle	139/419 X
1,368,215	2/1921	Stewart	139/419
1,603,982	10/1926	Riley	139/28
R28,155	9/1974	Dow	139/383 R

FOREIGN PATENTS OR APPLICATIONS

367,873	2/1932	United Kingdom	139/424

OTHER PUBLICATIONS

Textile Research Journal, Vol. 40, No. 11, November 1970, pages 986–996.

Textile Research Journal, Vol. 41, No. 8, August 1971, pages 637–647.

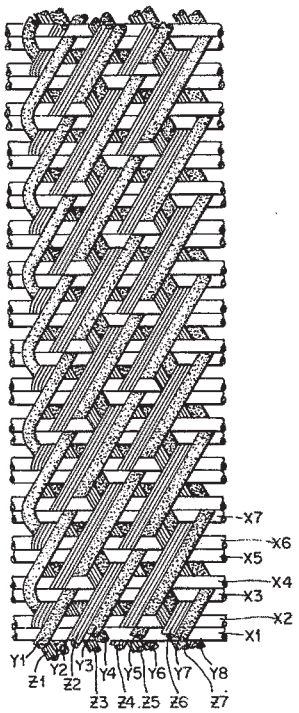
Primary Examiner—James Kee Chi

Attorney, Agent, or Firm—Miller, Frailey & Prestia

[57] **ABSTRACT**

Triaxial fabrics with weave patterns which provide relatively uniform porosity and uniform, isotropic compliancy with unstabilized lengths of yarn courses in each of the three yarn course sets. Three particular such weaves include two which are relatively nonporous and which include locked intersections to stabilize the woven structure, uniformly dispersed throughout the weave. A third weave includes no stabilized intersections and unlimited variation in the spacing between adjacent yarn courses and resulting porosity. In this third weave, a minimum thickness fabric is provided with optimum nesting characteristics of the three yarn courses.

10 Claims, 3 Drawing Figures



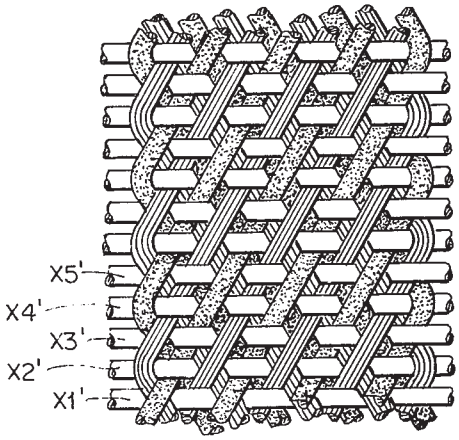


Fig. 2

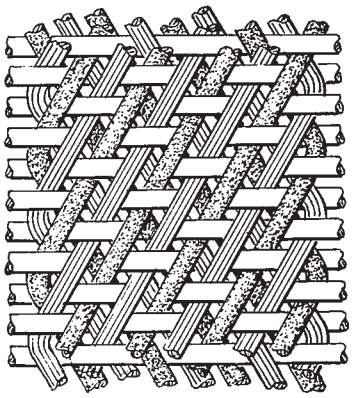


Fig. 3

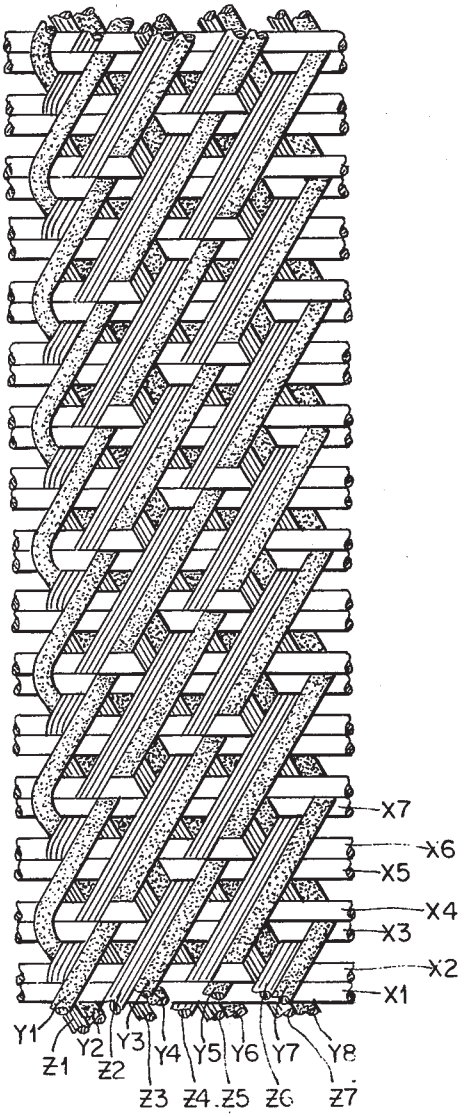


Fig. 1

TRIAXIALLY WOVEN FABRICS OF UNIFORM COMPLIANCY AND POROSITY

This invention relates to triaxially woven fabrics and particularly to such fabrics with a controlled degree of compliancy and porosity providing optimum conformability of the fabric to curved surfaces for purposes of reinforcement in curved products or for other special applications. More particularly, this invention pertains to three such weaves providing either a controlled degree of isotropic stability in the fabric structure or unlimited variation in porosity with optimum nesting characteristics.

A variety of triaxially woven fabric structures are known in the prior art. In some cases, these prior art triaxial fabrics have been very porous with the pore openings having a variety of shapes and sizes. Moreover, many of these prior art fabrics have not been stabilized except by the frictional effect of the interwoven yarn courses. One such woven structure is that seen in the U.S. Pat. No. 1,368,215—Stewart.

Relatively stable, isotropic fabrics, substantially stabilized by snugly compacted interlocked intersections, have been disclosed and claimed in U.S. Pat. No. 3,446,251, of common inventorship and assignment herewith. While the variety of weave patterns disclosed in that patent included certain relatively non-porous weaves, such as those seen in FIGS. **3, 4, 7, 9, 10** and **12** through **15,** these weaves have all resulted in fabric structures which are relatively dense and thick. Certain of the fabrics disclosed in that patent, such as the fabric shown in FIG. **6,** did include pore openings of uniform size and shape. Still further, that patent disclosed that certain stabilized triaxial weaves could be adapted for specific purposes by the provision of unlocked yarn courses, i.e., yarn courses in which lateral displacement is not prevented by snugly compacted interlocked intersections. Such weaves with so-called "long float lengths" are seen in FIGS. **14** and **15.**

Notwithstanding all of these prior art teachings, there has remained the need for triaxial fabrics with controlled or limited porosity of uniform pore size and shape with some compliancy throughout the weave, and particularly relatively uniform isotropic compliancy.

It is the general object of the invention to provide such triaxially woven fabric structures which are relatively compliant.

It is a more specific object of this invention to provide such isotropic compliant triaxial weaves with uniform or controlled porosity and controlled fabric density and thickness.

It is a still further object of this invention to provide such weaves which are either relatively stable by virtue of uniformly dispersed interlocked intersections throughout the weave or are rendered substantially compliant by the absence of such interlocked intersections.

These and other objects are met, in accordance with the present invention by a variety of triaxially woven fabric structures having repetitive weave patterns with relatively uniform porosity. The weaves of this invention further include stabilized yarn lengths in each of the three yarn course sets of the weaves, the unstabilized yarn course lengths in each case crossing at least two of the intersecting yarn courses of one of the remaining yarn course sets. These unstabilized yarn course lengths provide the compliance necessary in the fabrics of the present invention and do so in a manner which does not upset the otherwise desirable isotropic physical properties of the triaxial weave.

Three preferred forms of the present invention are those shown in FIGS. **1** through **3** of this application. This invention may be better understood by reference to the following detailed description of these weaves, taken in conjunction with the accompanying FIGS. **1–3,** and the Claims appended hereto.

In the drawings:

FIG. **1** is an illustration of a relatively stable, non-porous triaxially woven fabric with a controlled degree of compliance throughout the weave;

FIG. **2** is also a compliant; relatively stable triaxial weave of little or no porosity; and

FIG. **3** is a highly compliant triaxial weave readily adaptable to a wide variation in density and porosity, the pore openings of which nevertheless are of uniform size and shape.

Turning more specifically to FIG. **1,** there is shown a triaxial weave sometimes referred to as the "bi-satin" weave. This is essentially a non-porous weave of comparable density to that of a non-porous orthogonal weave of the same denier yarn. The weave of FIG. **1** provides relatively uniform compliance in all directions due to the presence of unstabilized lengths of yarn in each of the three yarn course directions. This refers to the lengths of the yarns between the points at which the yarns are locked by snugly compacted intersections with intersecting yarns so as to prevent lateral displacement of the locked yarn. These unstabilized lengths in each case cross over at least two yarn courses of one of the remaining yarn course sets. The presence of unstabilized yarn lengths in each of the three directions of the yarn course sets permits the fabric woven in accordance with FIG. **1** to yield slightly providing a greater tear strength than would otherwise be present and also permitting accurate conformation of the fabric to complex shapes, particularly where this is necessary for reinforcement of a molded article.

The weave of FIG. **1** includes three yarn course sets consisting of paired parallel yarn courses, each of which intersects the yarn courses of remaining sets to form angles of about 60°. Paired abutting yarn courses with a spacing of approximately one yarn diameter between such paired abutting yarn courses form an array comprising the yarn course sets. One of these yarn course sets is referred to herein as the wefts. The weft yarn courses are horizontal in the drawing of FIG. **1,** but their disposition may be more accurately described as lying perpendicular to the length of the fabric which extends from top to bottom in the illustration of FIG. **1.** The remaining two yarn course sets are referred to herein as the 1 o'clock and the 11 o'clock warp sets, respectively, corresponding approximately to the direction of a line on a clock face through the center of the clock and extending toward the 1 o'clock and 11 o'clock directions. For purposes of describing the fabrics of the present invention, in some cases the 12 o'clock or 6 o'clock direction will be referred to, this being the direction along the length of the fabric either upward or downward as seen in an illustration such as that of FIG. **1.**

Referring again more specifically to the woven fabric of FIG. **1,** it will be noted that the 1 o'clock warps in each case pass over or lie above the 11 o'clock warps throughout the fabric. With respect to the 1 o'clock

warps, each weft passes under one and over five such 1 o'clock warps. With respect to the 11 o'clock warps, each weft passes successively over one and under five such 11 o'clock warps. The combined over and under path of each weft with respect to both the 1 o'clock and 11 o'clock warps varies from weft to weft depending upon the relative lateral position of the 11 o'clock warp which the weft passes over and the 1 o'clock warp which the weft passes under. This varies in a four weft cycle such that the fifth weft path corresponds to that of the first weft path of the previous cycle. Laterally, of course, the pattern repeats itself with every seven warps.

The fabric pattern is then defined by the path of four successive wefts starting, for example, with weft X_3 which passes, from left to right, first under 11 o'clock warp Y_2, then over 1 o'clock warp Z_1, then over the next successive five 11 o'clock warps Z_3, Y_4, Z_5, Y_6, and Z_7 and under the next successive five 1 o'clock warps, Y_1, Z_2, Y_3, Z_4, and Y_5. Weft X_3 then passes under the next 11 o'clock warp Y_8 and over the next 1 o'clock warp Z_6 to begin a repetition of the lateral cycle. The next successive weft in a 12 o'clock direction from weft X_3 is weft X_4 which passes under all of the 1o'clock warps except Y_1 and over all of the 11 o'clock warps except Z_5. Again, the next weft in the 12 o'clock direction, weft X_5, passes under all of the 1 o'clock warps excpet Z_2 and over all of the 11 o'clock warps except Y_6; and the next succeeding weft, weft X_6, passes under all 1 o'clock warps except Y_3 and over all 11 o'clock warps except Z_6.

The next weft, weft X_7, then follows precisely the same pattern as weft X_3. It should be noted that the successive wefts pass over individual 1 o'clock warps one warp space to the right from that in the previous weft while the 11 o'clock "under" warps traverse with successive wefts three, one, three and one warp spaces to the right.

As seen in FIG. **1**, abutting pairs of parallel yarn courses are formed by wefts X_3 and X_4, wefts X_5 and X_6, and warps (at the longitudinal position of weft X_3) Y_1 and Z_1, and Z_2 and Y_3, Z_4 and Y_5, Z_6 and Y_7, Z_3 and Y_4, Z_5 and Y_6, and Z_7 and Y_3.

By providing a total number of warps in the 11 o'clock and 1 o'clock warp sets (in a weave of the type shown in FIG. **1**) which is divisible by **15** a desirable selvage configuration is possible. In this selvage edge configuration, each 11 o'clock warp intersects with the edge of the fabric at a weft position where that 11 o'clock warp passes over the weft and its lateral direction is reversed so that it becomes a 1 o'clock warp. At the opposite edge of the fabric, each 1 o'clock warp intersects the edge of the fabric at a weft position where it passes under that weft so that it is laterally reversed into an 11 o'clock warp. This selvage provides a stable edge configuration and is particularly adapted to certain triaxial fabric weaving equipment.

Referring now to FIG. **2**, there is shown what is known as the "double basic" stabilized triaxial weave. This weave may be visualized as two "basic" weaves, of the type shown in FIG. **1** of U.S. Pat. No. 3,446,251, interwoven with one another. The nominal space between yarns in this weave is one half a yarn diameter. The pattern for this weave starting with any specific weft yarn, such as weft X_1', is that it goes under and over successive 11 o'clock warp yarns on a one by one basis, and also under and over successive 1 o'clock yarns. The next successive weft, such as weft X_2', does the same thing; however, it passes over and under identically the same yarns in the 1 o'clock warp courses as the preceding weft, X_1', while following exactly an opposite path with respect to specific 11 o'clock warps and the preceding weft. In the next weft along the length of the fabric, i.e., the next weft in a 12 o'clock direction from the preceding weft, X_3', the pattern remains the same with respect to specific 11 o'clock warps as in the preceding weft and is reversed with respect to specific 1 o'clock warps. Thus the third weft, X_3', follows a pattern exactly opposite that of the first weft, X_1', with respect to specific 1 o'clock and 11 o'clock yarns. This pattern continues such that the path of weft X_5' is the same as that of weft X_1'.

The weave of FIG. **2** is also relatively non-porous and has a density comparable to that of the weave of FIG. **3** of U.S. Pat. No. 3,446,251, which is equivalent to that of a tightly woven orthogonal weave of yarns of the same denier. In that prior art weave, however, the yarn courses are paired rather than equally spaced from one another. Further, in this weave of the present invention, there are relatively longer lengths between the points of stabilization or interlocked intersections so that the weave is more compliant than that shown in FIG. **3** of the prior art patent referred to.

It is important to note that in this double basic weave shown in FIG. **2**, the fabric can be easily woven on equipment adapted to produce the "basic weave" of FIG. **1** in U.S. Pat. No. 3,446,251. More specifically, the basic equipment would be set up to weave the fabric of FIG. **2** of the present invention and could be adapted to produce the FIG. **1** weave of U.S. Pat. No. 3,446,251, by the simple omission of every other warp and weft.

As noted above, this weave of the present invention is somewhat compliant and therefore more readily conforms to the complex shape of a molded article in which it serves as a reinforcement. In addition, this compliance causes the fabric to have some yield resulting in an enhanced tear strength.

The weave as shown in FIG. **2** has a selvage configuration similar to that described with respect to the weave of FIG. **1** which also adapts this form of the invention to be woven in certain triaxial fabric manufacturing equipment.

In FIG. **3** is shown what is known as the "substrate" weave. This weave is not inherently stable by virtue of interlocked intersections. It is however, adaptable to receive the same selvage treatment as that of the weaves shown in FIGS. **1** and **2** and to be woven in triaxial fabric manufacturing equipment of the type in use for manufacturing other triaxial fabrics heretofore described. In the weave of FIG. **3**, all of the yarns are equally spaced from adjacent yarns in each yarn course set; this spacing, however, is unlimited and may vary from zero to any desired amount of space depending on the desired degree of porosity in the fabric. With small inter-yarn spacings, this weave provides optimum nesting of yarn courses and essentially a minimum thickness, low porosity fabric which may in itself have particular desirable characteristics. When adjacent yarn courses abut one another, a maximum density fabric, which is approximately 150 percent of the density of a tightly-woven orthogonal weave of yarns of the same denier, is produced.

As shown in FIG. 3, this fabric is woven with a one-half yarn diameter spacing between adjacent yarn courses resulting in a fabric density equal to that of a tightly woven orthogonal weave of yarns of the same denier and also roughly equivalent to that of the fabrics described above and shown in FIGS. 1 and 2.

In all of these weaves, a fabric is provided having compliance which is relatively uniform in all directions for optimum compatibility with molding material. In FIG. 3 the size and shape of the pore openings is also highly uniform providing adaptability to impregnation for reinforcement applications.

In the weave of FIG. 3, as in the weaves previously described and illustrated herein, all 1 o'clock warps pass over all 11 o'clock warps and each weft passes over one 1 o'clock and under the next two 1 o'clock warps while passing over the 11 o'clock warps on either side of the odd or "over" 1 o'clock warp. Adjacent the odd or "under" 11 o'clock warp, the weft passes under the next two adjacent 11 o'clock warps. This pattern repeats itself being displaced laterally one warp space distance between adjacent wefts.

The weave of FIG. 3 is also desirable in various applications because of its minimum thickness characteristic. This results from the nesting property previously referred to.

In summary, while this invention has been described with respect to specific embodiments, it should be understood that minor variations would be apparent to those skilled in the art and the appended claims are intended to cover such minor variations which come within the true spirit and scope of the present invention. Furthermore, the drawings of the specific embodiments, illustrated in the present invention, are idealized in that individual yarns are, to some degree crimped where one yarn intersects another. Generally, this invention, as exemplified and illustrated above, resides in the development of triaxial fabric weave patterns with relatively uniform porosity wherein the pattern includes unstabilized lengths of yarn in each yarn course set to provide fabric compliancy and yield for enhanced tear strength. Further, these weaves are designed to provide such compliancy in a relatively isotropic manner, i.e., in all directions within the plane of the fabric. This compliancy results from the incorporation in the weaves of this inventions of unstabilized lengths of yarn courses in each yarn course set which cross at least two intersecting yarn courses of one of the remaining yarn course sets.

The following is claimed:

1. In a triaxially woven fabric comprising three sets of parallel yarn courses, the yarn courses of each set forming an angle of approximately 60° with the intersecting yarn courses of each other set, the improvement consisting of a repetitive weave pattern with relatively uniform porosity said pattern including unstabilized lengths of yarn courses in each yarn course set, said unstabilized lengths in each yarn course set crossing at least two intersecting yarn courses of one of the remaining yarn course sets, said unstabilized lengths providing some compliancy to the fabric, said compliancy being relatively isotropic in the plane of the fabric.

2. In a triaxially woven fabric comprising three sets of parallel, paired yarn courses, the courses of each pair lying next to one another and spaced from adjacent parallel paris by a distance of one yarn diameter, one of said sets comprising wefts disposed perpendicular to the length of said fabric and the other of said sets comprising 11 o'clock and 1 o'clock warps, respectively, the yarn courses of each set forming angles of approximately 60° with the intersecting yarn courses of each of said remaining sets, all of said 1 o'clock yarn courses passing over all intersecting 11 o'clock yarn courses, the improvement consisting of a compliant, repetitive weave pattern in which

a. a first weft passes from left to right, under a first 11 o'clock warp then over paired second and third 11 o'clock warps, while at the same time passing over a first 1 o'clock warp and under a second 1 o'clock warp paired therewith, thence over paired fourth and fifth 11 o'clock warps and under paired third and fourth 1 o'clock warps, and thence over a sixth 11 o'clock warp and under a seventh 11 o'clock warp paired therewith and under paired fifth and sixth 1 o'clock warps, said seventh 11 o'clock warp corresponding to said first 11 o'clock warp in the next lateral repetition of the weft path;

b. a second weft, forming a pair with said first weft and being disposed parallel thereto but removed in a 12 o'clock direction therefrom, said second weft passing over all of said 11 o'clock warp except said fourth warp which it passes under and under all of said 1 o'clock warps, except said second 1 o'clock warp which it passes over;

c. a third weft disposed parallel to said second weft and displaced in a 12 o'clock direction from said second weft and spaced one yarn diameter therefrom, said third weft passing under all of said 1 o'clock warps and over all of said 11 o'clock warps, except said third 1 o'clock warp which it passes over and said fifth 11 o'clock yarn which it passes under;

d. a fourth weft, paired with and parallel to said third weft and disposed in a 12 o'clock direction therefrom, said fourth weft passing under all of said 11 o'clock warps, except said fourth 1 o'clock yarn which it passes over and under an eighth 11 o'clock yarn lying adjacent and paralleling said seventh 11 o'clock yarn spaced one yarn diameter thereform.

3. In a triaxially woven fabric, as recited in claim 2, the further improvement consisting of selvage edges formed by reversing the lateral direction of each of said 11 o'clock warps at an intersection of said warp with the edge of said fabric at a weft position wherein said 11 o'clock warp passes over said weft and by reversing the lateral direction of each of said 1 o'clock warps at an intersection of said warp with the edge of said fabric at a weft position wherein said 1 o'clock warp passes under said weft.

4. In a triaxially woven fabric, as recited in claim 3, the further improvement consisting of providing a total number of warps in said warp yarn sets which is divisible by 15.

5. In a triaxially woven fabric comprising three sets of parallel yarn courses, the intersecting courses of each forming angles of approximately 60° with one another, one of said sets comprising wefts running perpendicular to the length of said fabric and the other two of said sets comprising 1 o'clock and 11 o'clock warps, respectively, said 1 o'clock warps overlying said 11 o'clock warps throughout the fabric, the improvement consisting of a compliant repetitive weave pattern in which said wefts pass from left to right, alternatively

over and under successive 11 o'clock warps and also over and under successive 1 o'clock warps;

a. a first weft woven, with reference to the adjacent weft disposed parallel to and removed in the 6 o'clock direction therefrom and to specific 1 o'clock and 11 o'clock warps, such that the over-under pattern is exactly opposite that of said reference weft with said 11 o'clock warps and the same as that of said reference weft with said 1 o'clock warps;

b. a second weft, adjacent said first weft and disposed parallel to and removed in the 12 o'clock direction therefrom, woven, with reference to said first weft and to specific 1 o'clock and 11 o'clock warps, such that the over-under pattern is the same as that of said first weft with said 11 o'clock warps and opposite that of said first weft with said 1 o'clock warps;

c. a third weft, adjacent and parallel to said second weft and removed in the 12 o'clock direction therefrom, woven, with reference to said second weft and to specific 1 o'clock warps, such that the over-under pattern is opposite that of said second weft with said 11 o'clock warps and the same as that of said second weft with said 1 o'clock warps.

6. In a triaxially woven fabric as recited in claim **5,** the further improvement consisting of selvage edges formed by reversing the lateral direction of each of said 11 o'clock warps at an intersection of said warp with the edge of said fabric at a weft position wherein said 11 o'clock warp passes over said weft and by reversing the lateral direction of each of said 1 o'clock warps at an intersection of said warp with the edge of said fabric at a weft position wherein said 1 o'clock warp passes under said weft.

7. In a triaxially woven fabric, as recited in claim **6,** the further improvement consisting of providing a total number of warps in said warp yarn sets which is divisible by 4.

8. In a triaxially woven fabric comprising three sets of parallel yarn courses with equal spacing therebetween throughout the fabric, the intersecting courses of each forming angles of approximately 60° with one another, one of said sets comprising wefts running perpendicular to the length of said fabric and the other two of said sets comprising 1 o'clock and 11 o'clock warps, respectively, said 1 o'clock warps overlying said 11 o'clock warps throughout the fabric, the improvement consisting of a compliant repetitive weave pattern in which a first weft passes successively under a first 1 o'clock warp, over a first 11 o'clock warp, over a second 1 o'clock warp, over a second 11 o'clock warp, under a third 1 o'clock warp and under a third 11 o'clock warp, said pattern being laterally transposed one warp yarn position to the right with each successive weft, such that a second weft adjacent said first weft and disposed in the 12 o'clock direction therefrom, passes over said third 1 o'clock warp and under the two adjacent 1 o'clock warps on either side thereof, and also passes under said second 11 o'clock warp and over the two adjacent 11 o'clock warps on either side thereof.

9. In a triaxial fabric as recited in claim **8,** the improvement wherein the adjacent yarn courses in each of said sets abut one another.

10. In a triaxially woven fabric as recited in claim **8,** the further improvement consisting of selvage edges formed by reversing the lateral direction of each of said 11 o'clock warps at an intersection of said warp with the edge of said fabric at a weft position wherein said 11 o'clock warp passes over said weft and by reversing the lateral direction of each of said 1 o'clock warps at an intersection of said warp with the edge of said fabric at a weft position wherein said 1 o'clock warp passes under said weft.

* * * * *

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 3,874,422

DATED : April 1, 1975

INVENTOR(S) : NORRIS F. DOW

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

Column 4, line 3, "1" should read --11--;

Column 4, line 5, "11" should read --1--;

Column 4, lines 8 and 9, "re- mains the same" should read --is reversed--;

Column 4, line 10, "reversed" should read --the same--.

Signed and Sealed this

Thirteenth Day of *March 1979*

[SEAL]

Attest:

RUTH C. MASON
Attesting Officer

DONALD W. BANNER
Commissioner of Patents and Trademarks

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 3,874,422

DATED : April 1, 1975

INVENTOR(S) : Norris F. Dow

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

Col. 1, line 63, "stabilized" should read --unstabilized--.

Signed and Sealed this

Twentieth Day of *September 1983*

[SEAL]

Attest:

GERALD J. MOSSINGHOFF

Attesting Officer *Commissioner of Patents and Trademarks*