

[54] **CIRCULAR WEAVING APPARATUS
PRODUCT AND PROCESS**

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[22] Filed: **Dec. 31, 1968**

[21] Appl. No.: **793,921**

[52] U.S. Cl. **139/387**

[51] Int. Cl. **D03d 3/02**

[58] Field of Search.....139/383, 384, 387, 388,
408-415

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Primary Examiner—Henry S. Jaudon

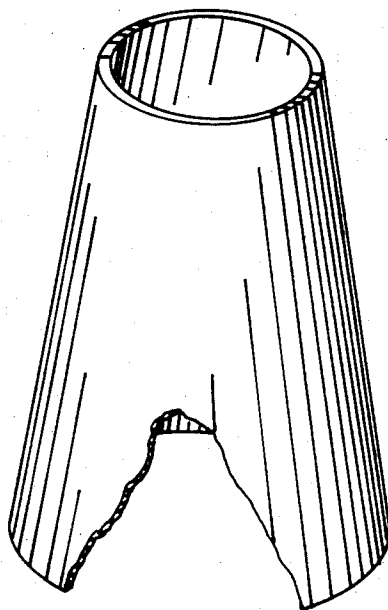
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[57]

ABSTRACT

A thick-walled, integrally woven, three-dimensionally shaped fabric which is produced on a circular type weaving machine is comprised of a plurality of yarn systems each of which defines a plurality of yarn planes with the yarn planes of each yarn system being distinct and traversing selected yarn planes of the other yarn systems. The fabric is woven upon the surface of a mandrel with the resulting shape being determined by the action of Jacquard means on the yarn systems and by the three-dimensional shape of the mandrel. The resulting fabric may be woven in the shape of a cylinder, a truncated cone, or as irregular shapes, such as, an airplane wing, a boat hull or the like.

30 Claims, 35 Drawing Figures



PATENTED MAR 6 1973

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SHEET 1 OF 5

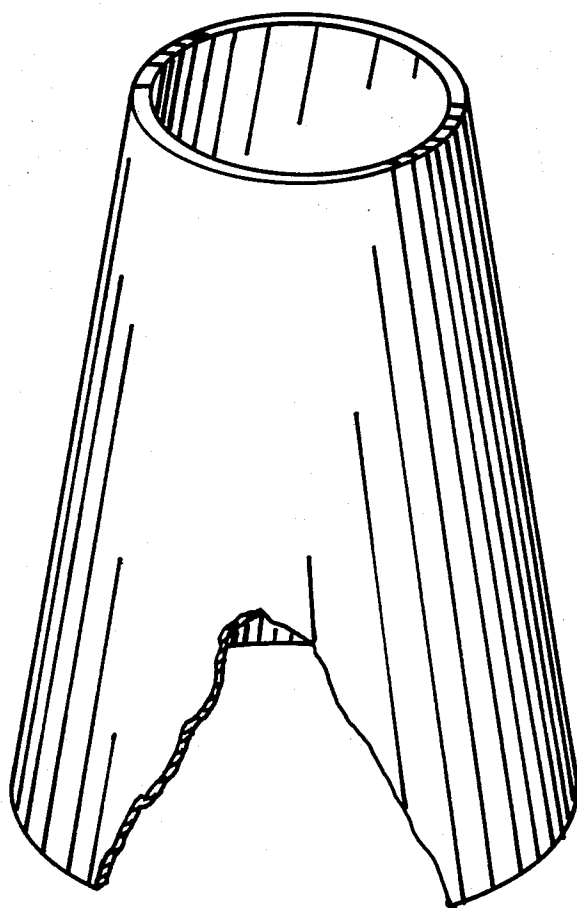


FIG. 1

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BY *J. Bowen Rose, Jr.*
ATTY.

FIG. 3

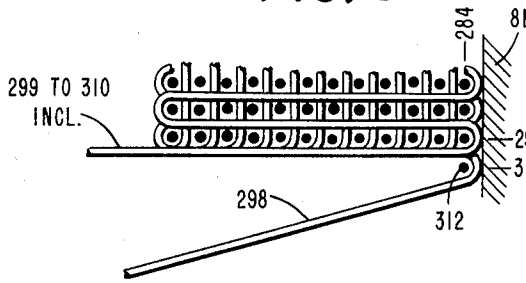


FIG. 4

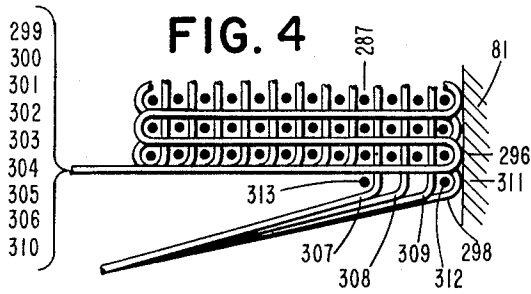


FIG. 5

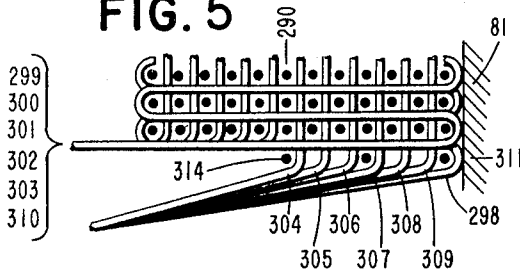


FIG. 6

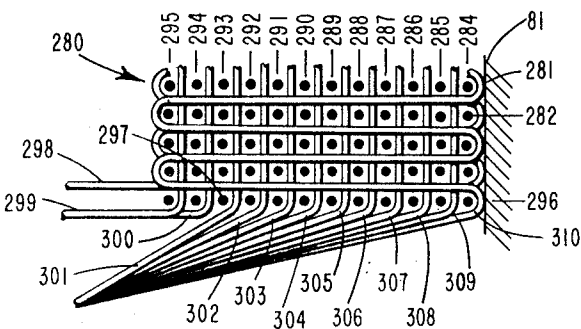
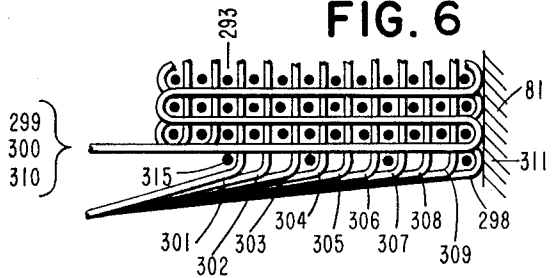


FIG. 7

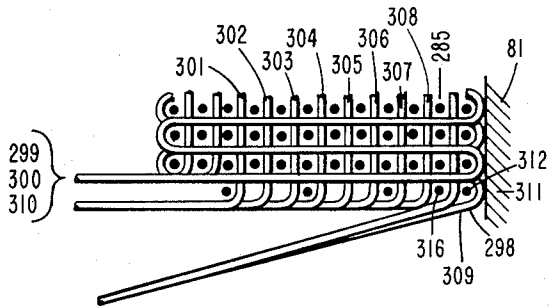


FIG. 8

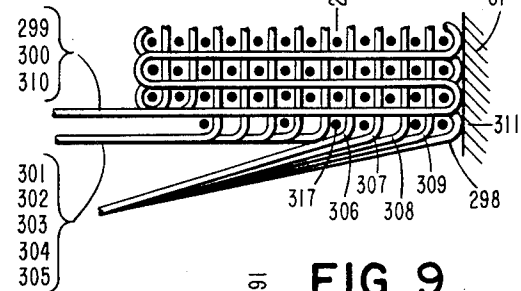


FIG. 9

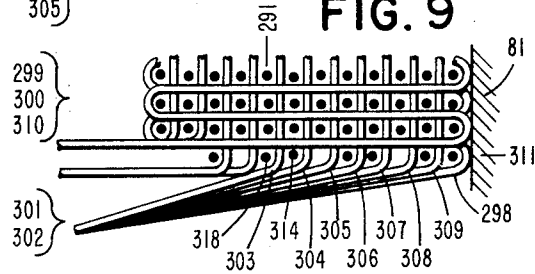


FIG. 10

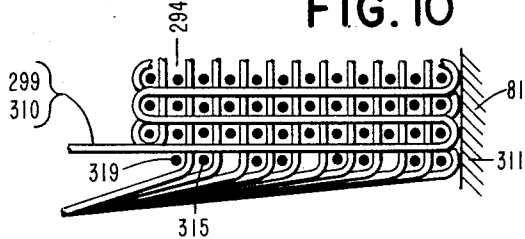
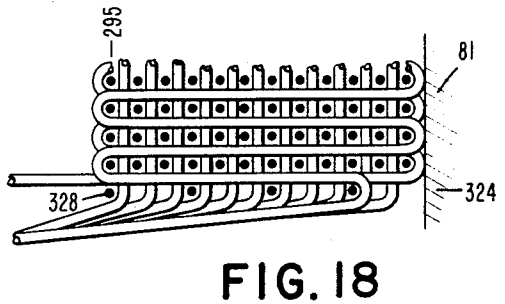
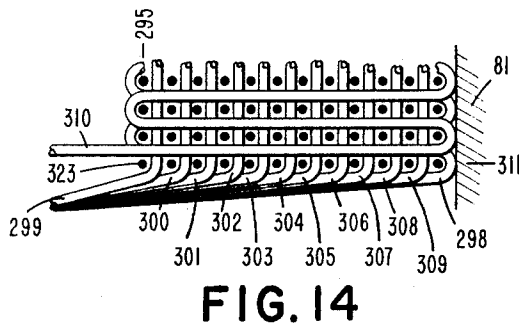
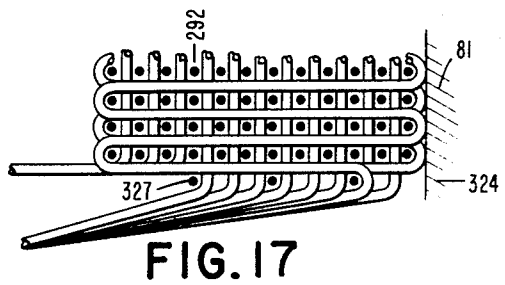
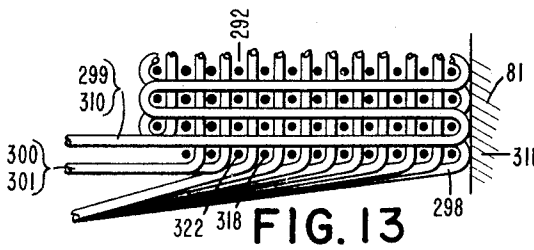
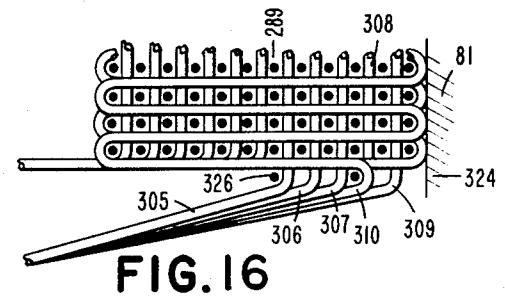
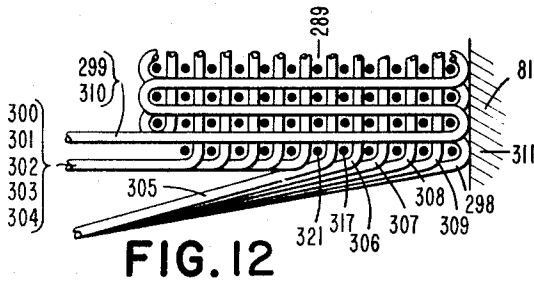
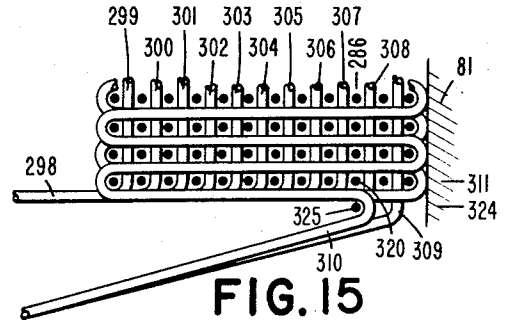
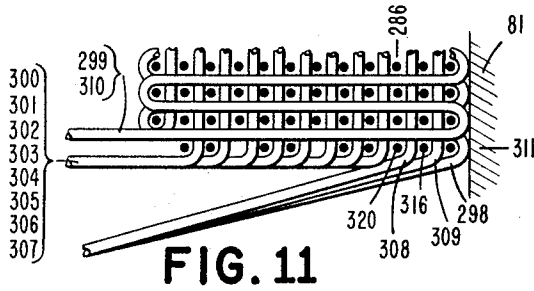
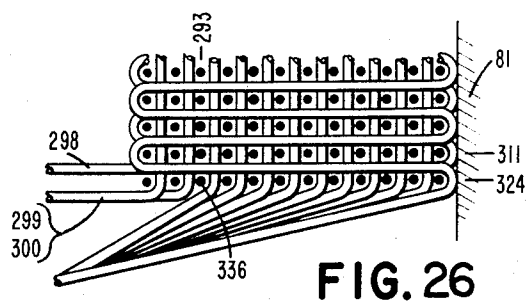
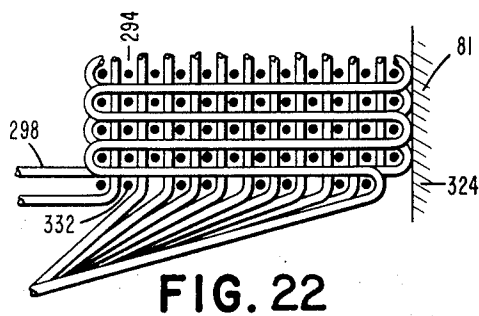
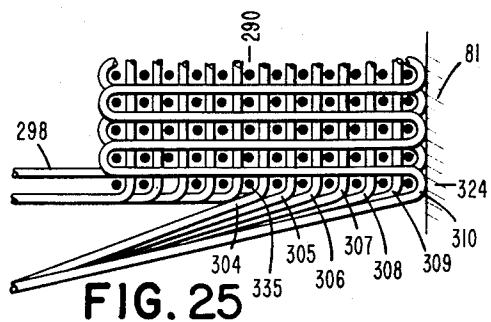
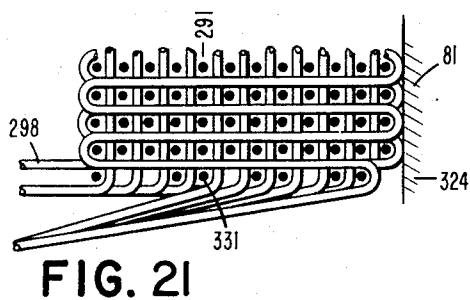
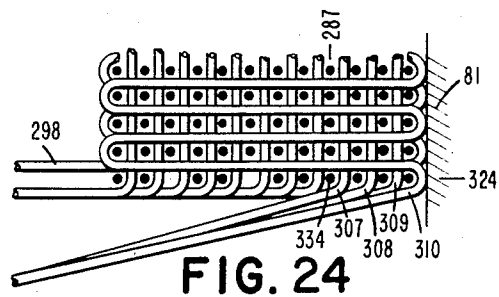
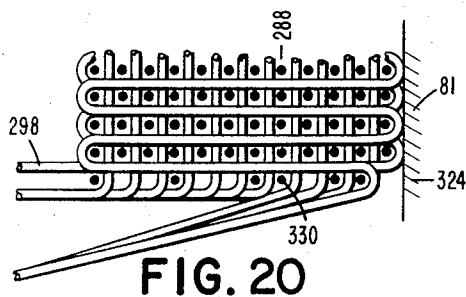
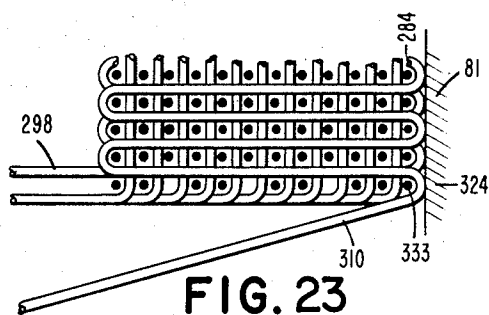
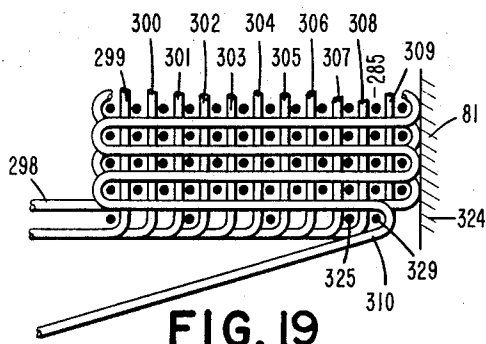
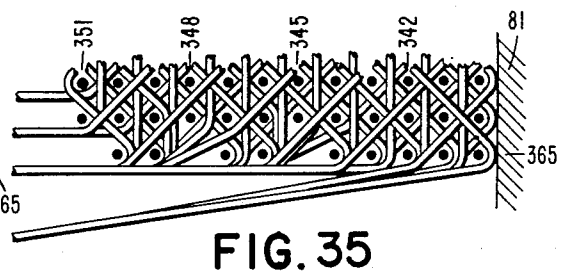
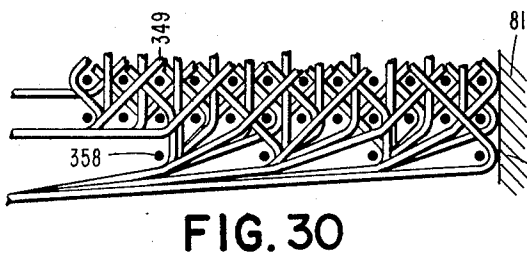
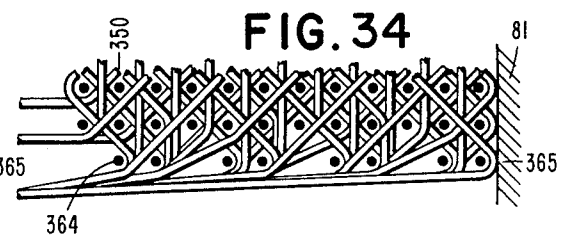
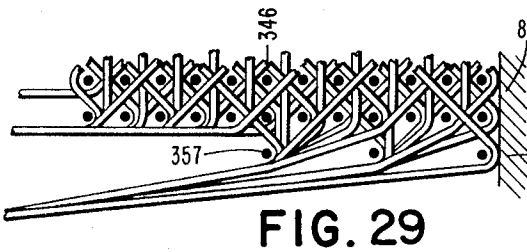
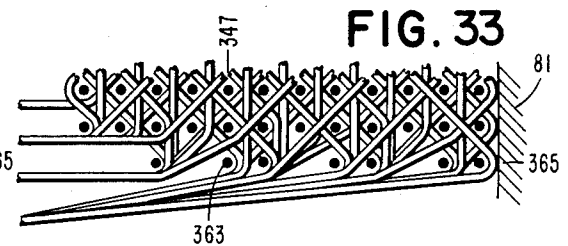
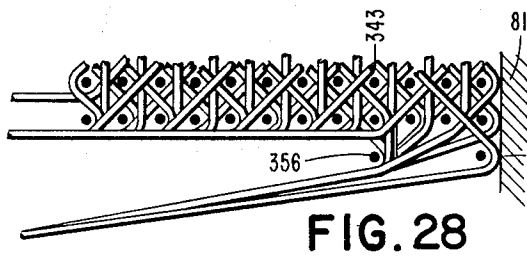
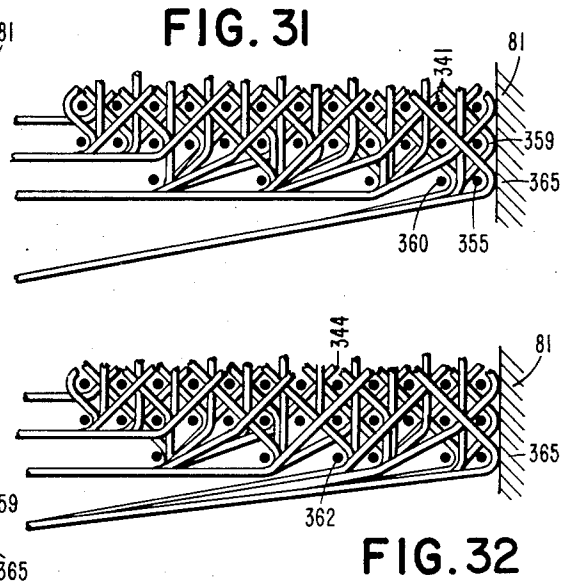
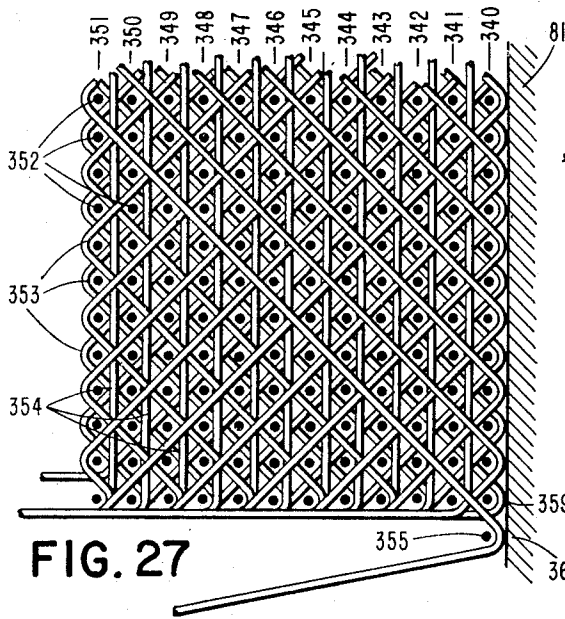


FIG. 2







CIRCULAR WEAVING APPARATUS PRODUCT AND PROCESS

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to the formation of an integrally woven, shaped fabric and more particularly, to a fabric which is woven in accordance with a predetermined pattern, the pattern providing a curvilinear design and a fabric thickness so as to provide a three-dimensionally shaped article having walls comprised of yarn systems which provide reinforcement against stress in three mutually perpendicular planes.

2. Description of the Prior Art

With the advent of certain high performance fibers such as carbon, graphite, quartz, steel, certain organic polymeric fibers including the polyimides which are resistant to high temperatures and which exhibit excellent tensile properties when subjected to high temperatures, a need has arisen for shaped, three-dimensionally woven fabrics which are produced with a relatively high degree of accuracy to conform to a predetermined configuration and which have relatively high strength and good uniformity of density throughout. Such fabrics are especially advantageous in the fiber reinforced plastics industry where the shaped articles are impregnated with a resin which is subsequently cured to form a composite structure. The resulting composite is light in weight, has excellent strength per unit weight and is extremely useful in the aircraft industry, pressure vessels and the like. Such articles may be formed in a variety of ways including filament winding, the weaving of multi-layered articles on flat looms with the resulting article being opened up to assume a particular shape, and the weaving by means of circular looms. A particular process for filament winding is disclosed in U. S. Pat. No. 3,260,398 to Levenetz. The Levenetz patent has fibers oriented in such a manner as to be aligned with the forces developed about the openings in a structure by having circumferentially wound filaments and a radial fill. The filaments forming the radial fill with the particular forces exerted thereon more efficiently support the developed loads since the filaments are not actually entwined with the other filaments; however, the structure becomes very weak to forces applied in the lateral direction.

A recent development in the filament winding art provides a three-dimensional fabric which encompasses, in addition to the basic filament winding concept the addition of reinforcement in the Z-direction. This is accomplished through the utilization of a jig or fixture having positioned therein spaced apart metal tubes aligned in the Z-direction. Filaments are threaded between the tubes to form alternate plies of aligned reinforcements. When sufficient cross-plies are laid down to produce the required thickness, they are compressed and the steel tubes are removed. Thereafter, bundles of filaments are threaded through the holes left by the tubes to form the Z-direction reinforcement.

Other shaped fabrics are generally disclosed in U. S. Pat. Nos. 3,102,559, 3,090,406 and 3,234,972 to Koppelman et al. Fabrics of this type are woven on a flat loom using one or more shuttles and Jacquard means to raise certain warp yarns above the general plane of weaving to form additional sheds. The shuttles are then

advanced through the various sheds to form a woven fabric in the conventional manner. The resulting fabric is then opened out and, if impregnation is desired, impregnated and placed on a mandrel while the resin cures. In all fabrics of this type, the selvage areas, as woven, are weak due to the lack of warp yarns in areas which are transverse to the direction of the force applied on the same.

Multi-ply tubular fabric has been made on circular looms; however, the two plies are not interconnected, but one ply is woven on top of the other ply to eliminate the expensive and time-consuming step of pulling a first ply through the second one. An example of such articles are disclosed by U. S. Pat. No. 1,357,967 to Dupray.

Other art of interest includes the braiding process whereby layers of helically wound and interlocked yarn are woven in a cylindrical shape with the interlocks being produced at every intersection of the yarn. Further, needled fabric felts are available and are produced by forcing fibers vertically through horizontally arranged layers of fabric which mechanically link them together. Layered fabrics may also be produced by causing selected fibers of one layer to be locked into the piles and loops of another layer.

From a review of the prior art, it is obvious that a definite need exists for a fabric which includes woven thickness as well as assuming a three-dimensional curvilinear shape.

SUMMARY OF THE INVENTION

The thick-walled articles of this invention consist of fabrics comprised of at least three warp and two filling yarns in thickness and which are woven upon the surface of a mandrel. Depending upon the end use to which the articles may be employed, the fabric may be woven to have a substantially uniform fabric density. The thick walls in general are comprised of a plurality of yarn systems which, for simplicity, may be called filling yarns, locker warp yarns and stuffer warp yarns. The filling yarns are substantially equivalent to the weft yarns in a conventional flat fabric while the locker warp yarns are equivalent to the warp yarns thereof. The stuffer warp yarns normally are woven in planes perpendicular to the general planes in which the filling yarns reside. Each of the yarn systems includes a plurality of yarn planes each of which is comprised of one or more strands of yarn. Each of the yarn planes is distinct and traverses selected yarn planes of the other yarn systems. For example, in a thick-walled tubular, selvage free fabric producible by the apparatus of this invention, a particular weave pattern provides stuffer warp yarns arranged in planes that extend radially outward from the longitudinal axis of the fabric and lengthwise thereof. The filling yarn picks to be herein after described lie in a series of parallel planes which are normal to the longitudinal axis of the fabric. The locker warp yarns form planes that sequentially alternate with the stuffer warp yarn planes and are substantially parallel thereto. Thus, for the pattern described, the filling yarns traverse both the stuffer and locker warp yarn planes. In weaving a cylinder of the type described, the stuffer and locker warp yarns may be combined into a single yarn system comprised of a plurality of yarn planes which traverse the filling yarn planes.

Therefore, an object of this invention is to provide thick-walled, integrally woven, three-dimensionally shaped fabrics.

Another object of this invention is to provide a shaped, thick-walled fabric which is comprised of a plurality of yarn systems each of which defines a plurality of yarn planes with the yarn planes of each yarn system being distinct and traversing selected yarn planes of the other yarn systems.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective, fragmented view of an integrally woven truncated cone;

FIGS. 2 through 26 are section views through a first fabric embodiment showing in sequence the manner in which two decks of filling yarns are woven into the fabric;

FIGS. 27 through 35 are section views through a second fabric embodiment showing portions of the sequence for weaving one deck of filling yarn into the fabric.

FIRST FABRIC EMBODIMENT

FIGS. 2-26 illustrate the segmented insertion of filling yarn in the weaving of a given fabric with the utilization of four filling yarn inserters. The fabric 280 comprises a plurality of locker warp yarns 281, a plurality of filling yarns 282, and a plurality of stuffer warp yarns 283.

Each horizontal row of filling yarns 282 will hereinafter be called a deck while each vertical row of filling yarns will be called a course which is not to be confused with the definition of a "course" in knitting. For a given fabric, the number of filling yarns forming a deck is dependent upon the required fabric thickness. For example, the embodiment shown in FIGS. 2-26 has 12 filling yarns per deck. The number of filling yarns forming a course will vary with the length of the fabric. The number of stuffer warp yarns across a given deck will vary with the thickness of the fabric and will be one less than the number of filling yarns, i.e., eleven stuffer warp yarns are employed in the embodiment depicted in FIGS. 2-26. For purposes of illustration, the courses of filling yarns are numbered 284, 285, 286, 287, 288, 289, 290, 291, 292, 293, 294, and 295.

The number of courses which may be woven into a given fabric is dependent upon the number of filling yarn inserters utilized in the weaving thereof. That is, the number of courses of which a given fabric may be comprised must be a whole number multiple of the number of filling yarn inserters employed in the weaving thereof. For example, if two filling yarn inserters were to be employed to weave the fabric of FIGS. 2-26, the first filling yarn inserter would be programmed to weave courses 284 through 289 and the second filling yarn inserter would be programmed to weave courses 290-295. Whenever more than one filling yarn inserter is employed each will be programmed to weave adjacent courses to prove an ordered yarn fabric.

In the instant example, the four filling yarn inserters may be called first, second, third and fourth with the first filling yarn inserter supplying filling yarn to courses 284, 285, and 286; the second filling yarn inserter supplying filling yarn to courses 287, 288, and 289; the third filling yarn inserter supplying filling yarn to courses 290, 291 and 292; and the fourth filling yarn in-

serter supplying filling yarn to courses 293, 294, and 295.

In reference to FIG. 2, deck 296 has been completed by the insertion of filling yarn 297 which is the last of such yarn to be placed in deck 296 for that particular sequence. It can be seen that locking warp yarns 298 and stuffer warp yarns 299 and 300 form the upper portion of the shed while stuffer warp yarns 301, 302, 303, 304, 305, 306, 307, 308, 309 and locking warp yarns 310 form the bottom portion of the shed. To prepare for the formation of deck 311, the shed is changed by the Jacquard heads so that stuffer warp yarns 299 through 309 and locker warp yarn 310 form the upper portion of the shed while locker warp yarn 298 forms the bottom portion of the shed. In FIG. 3, filling yarn 312 which is carried by first filling yarn inserter is carried through the shed formed as described immediately above and pulls locker warp yarn 298 inwardly until the same rests against the mandrel 81. Since first filling yarn inserter is immediately followed by second filling yarn inserter, the shed is changed by the Jacquard head (as shown in FIG. 4) so that the stuffer warp yarns 299 through 306 and the locker warp yarn 310 form the upper portion of the shed while stuffer warp yarns 307, 308 and 309 and locker warp yarns 298 forms the lower portion of the shed. In FIG. 4, filling yarn 313 is laid in the course 287 and remains there since stuffer warp yarn 307 prevents filling yarn 313 from being drawn closer to the mandrel 81 and filling yarn 313 is thereafter held in that position by the tension induced by second filling yarn inserter.

In FIG. 5, the filling yarn 314 is placed in course 290 by third filling yarn inserter. The upper portion of the shed is formed by the stuffer warp yarn 299 through 303 and locking warp yarn 310 while the lower portion of the shed is formed by stuffer warp yarn 304 through 309 and locker warp yarn 298. The shed as programmed by the Jacquard heads and as shown in FIG. 6 has its upper portion comprised of the stuffer warp yarns 299 and 300 and the locker warp yarns 310 and the lower portion of the shed is formed by stuffer warp yarns 301 through 309 and locker warp yarn 298. Filling yarn 315 is placed into course 293 by the fourth filling yarn inserter. It can now be seen that each of the filling yarn inserters has made one complete revolution.

In FIG. 7, filling yarn 316 is directed into course 285 by the shed which has its upper portion formed of stuffer warp yarns 299 through 308 and locker warp yarn 310 and the lower portion formed of stuffer warp yarns 309 and locker warp yarns 298. Filling yarn 316 is carried by first filling yarn inserter and in effect is a continuation of filling yarn 312.

In FIG. 8, the upper portion of the shed is comprised of the locker warp yarns 310 and stuffer warp yarn 299 through 305 and the lower portion of the shed is comprised of the locker warp yarn 298 and stuffer warp yarns 306 through 309. Filling yarn 317 is inserted in course 288 by second filling yarn inserter, filling yarn 317 being a continuation of filling yarn 313. In FIG. 9, the shed has its upper portion comprised of the stuffer warp yarns 299 through 302 and the locker warp yarn 310 has the lower portion of the shed comprised of the stuffer warp yarns 303 through 309 and the locker warp yarn 298. Filling yarn 318 is laid into course 291 by the third filling yarn inserter as a continuation of

filling yarn 314. In FIG. 10, the shed has its upper portion formed of locker warp yarn 310 and stuffer warp yarn 299. Filling yarn 319 is laid into course 294 by the fourth filling yarn inserter and is a continuation of filling yarn 315. It can be seen that the filling yarn inserters have made a second revolution and each has laid its yarn in the selected course.

The filling yarn deck 311 is completed by a third revolution of each of the filling yarn inserters; the beginning of which is shown in FIG. 11, wherein the upper portion of the shed is comprised of the stuffer warp yarns 299 through 307 and locker warp yarn 310 while the lower portion of its shed is comprised of the stuffer warp yarns 308 and 309 and locker warp yarn 298, the filling yarn 320 is inserted into course 286 by first filling yarn inserter and is a continuation of filling yarn 316. In FIG. 12, the shed has the upper portion thereof formed by stuffer warp yarns 299 through 304 and locker warp yarn 310 and has the lower portion thereof comprised of the stuffer warp yarns 305 through 309 and the locker warp yarns 298. Filling yarn 321 is laid into course 289 by means of the fourth filling yarn inserter with filling yarn 321 a continuation of filling yarn 317. In FIG. 13, the shed has its upper portion formed from stuffer warp yarns 299, 300 and 301 and locker warp yarn 310. The filling yarn 322 is inserted into course 292 by the third filling yarn inserter, filling yarn 322 being a continuation of filling yarn 318. In FIG. 14, deck 311 is completed. The shed therein has its upper portion formed by locker warp yarn 310 and has the lower portion of its shed formed by the locker warp yarns 298 and stuffer warp yarns 299 through 309. Filling yarn 323 is inserted into course 295 by means of the fourth filling yarn inserter.

In FIG. 15, the filling yarn deck 324 is begun by the first filling yarn inserter inserting the filling yarn 325 into the course 286 with the lower portions of the shed comprising the locker warp yarns 310 and the stuffer warp yarns 308 and 309. During the insertion of the filling yarn 325 into course 286 the tip of the first filling yarn inserter has forced the locker warp yarns 310 toward the mandrel surface. The filling yarn 325 is a continuation of the filling yarn 320 and is seen to reside in the same course 286.

Since both the filling yarns 320 and 325 are inserted by the same filling yarn inserter upon successive revolutions thereof it should be apparent that the first, second, third and fourth filling yarn inserters are programmed such that the tip thereof are neither retracted or extended between the completion of the weaving of one deck of filling yarns and the starting of the next successive deck. The latter mode of programming the retraction and extension of the filling yarn tips is utilized regardless of the weave pattern or the number of filling yarn inserters being employed to maintain an ordered fabric weave.

It can be seen that locker warp yarns 298 will remain in the upper shed until the filling yarn deck 324 is completed.

In FIG. 16, the shed is formed substantially like the shed shown in FIG. 11 with the filling yarn 326 being laid into the course 289 by means of the second filling yarn inserter. The filling yarn 326 remains in course 289 even though under tension, for stuffer warp yarns 305 prevent the same from moving toward the mandrel

81. In FIGS. 17 and 18, the sheds are formed as previously depicted in FIGS. 12 and 13 with filling yarns 327 and 328 respectively laid into courses 292 and 295 by means of third filling yarn inserters.

In FIG. 19, the shed has its upper portion formed by the stuffer warp yarns 299 through 308 and locker warp yarns 298 and the bottom portion formed by stuffer warp yarns 309 and the locker yarns 310. Filling yarn 329 which is a continuation of filling yarn 325 is passed through the shed and laid in the course 285 by first filling yarn inserter. Also viewing FIG. 15, it can be seen that the locker warp yarn 310 has its extremity moved inwardly from course 286 to 285 by means of the tip of the first filling yarn inserter. The filling yarn 329 is prevented from moving closer to the mandrel 81 and into course 284 by means of the stuffer warp yarns 309. In FIGS. 20, 21, and 22, the sheds for allowing filling yarn 330, 331 and 332 to be woven into the courses 288, 291 and 294 respectively by means of the second, third and fourth filling yarn inserters is much the same as has been described for the formation of the sheds for those particular courses.

The shed as shown in FIG. 23 has its upper portion comprised of all of the stuffer yarns and has its lower portion comprised only of the locking warp yarns 310. Thus, as first filling yarn inserter proceeds through the shed, the tension thereof draws the locker warp yarns 310 into a position adjacent the mandrel by placing filling yarn 333 in course 284. The filling yarn 333 is a continuation of the filling yarn 329. Thus, it can be seen that since the first filling yarn inserter only supplies such yarn to courses 284, 285, 286, all of the filling yarn in those courses are a continuation of each other. In FIGS. 24, 25 and 26, the filling yarns 334, 335 and 336 are respectively positioned into courses 287, 290 and 293 by means of second, third and fourth filling yarn inserters. The sheds are formed in essentially the same way as herein before set forth for the particular courses in question. Thus, upon the insertion of filling yarn 336, the complete cycle which includes filling yarn decks 311 and 324 is completed whereupon the procedure is repeated until the product is woven.

The FIGS. 2-26 show a fabric having a thickness of twelve filling yarns, eleven stuffer warp yarns and two locker warp yarns; however, this thickness may be varied over a space of several decks or from deck to deck if a contoured external surface of the woven product were required. This may be accomplished by providing sufficient additional stuffer warp yarns that are maintained external of the as woven fabric in the upper portion of the shed until such time as they are inserted into the weaving shed by the program of the Jacquard heads. Simultaneously with the insertion of the additional stuffer warp yarns into the weaving shed by the plurality of Jacquard heads of the yarn filling inserters would be programmed to extend and retract over a greater number of courses in accordance with the number of stuffer warp yarns to be added. As previously discussed the number of stuffer warp yarns which are to be added or subtracted from the fabric during the weaving process must be a whole number multiple of the number of filling yarn inserters being utilized. In the example at hand the stuffer warp yarns would have to be added or subtracted in multiples of four since four filling yarn inserters are being employed to weave the fabric.

It may be seen that the utilization of a single filling yarn inserter provides for the greatest flexibility with respect to increasing or decreasing the fabric thickness during weaving but has the disadvantage of providing the slowest rate of fabric production.

SECOND FABRIC EMBODIMENT

In FIGS. 27—35, a different pattern is depicted wherein the locker warp yarns as previously described are woven in a diagonal manner.

Filling yarns 352 are arranged in courses 340 through 351 and are separated both by locker warp yarns 353 and stuffer warp yarns 354. Depending upon the end use of the fabric, stuffer warp yarns 354 may or may not be incorporated into the fabric. The main purpose of such stuffer warp yarns 354 is to increase dimensional stability in the vertical direction. The particular pattern assumed by locker warp yarns 353 is controlled by the manipulation of the shed by means of the Jacquard heads, the pattern design being quite flexible and being limited only by the maintenance of such yarns in a given plane. For the embodiment shown, four filling yarn inserters are used with first filling yarn inserter laying in filling yarn 352 for courses 340, 341 and 342, second filling yarn inserter laying in filling yarn 352 for courses 343, 344 and 345, third filling yarn inserter laying in filling yarn 352 for courses 346, 347 and 348 and fourth filling yarn inserter laying in filling yarn 352 for courses 349, 350 and 351. The sequence for laying in filling yarns 352 is substantially the same as has been previously described for the first revolution of the filling yarn inserters, the four filling yarn inserters respectively lay in filling yarns 355, 356, 357 and 358 in courses 340, 343, 346, and 349. In order to preserve the diagonal pattern as set forth, locker warp yarn 359 immediately prior to and during the insertion of filling yarn 360 into course 341 by first filling yarn inserter is held in the lower part of the shed and therefore extends between filling yarn 360 and filling yarn 355. The second revolution of filling yarn inserters respectively inserts filling yarns 360, 362, 363 and 364 into courses 341, 344, 347 and 350. Deck 365 is completed upon the completion of the third revolution of each of the filling yarn inserters wherein filling yarns 352 are woven sequentially into courses 342, 345, 348 and 351. The immediately following deck is then sequentially woven into the fabric courses in the following order: 342, 345, 348, 351; 341, 344, 347, 350; 340, 343, 346 and 349. Upon the completion of the insertion of the filling yarn 352 into into course 349, the sequence is ready to be repeated starting again with the weaving of the filling yarn 352 into course 340.

It can be seen that by eliminating the stuffer warp yarn 354, a thick-walled intricately woven three dimensionally shaped fabric may be woven with only two yarn systems, those being filling yarns 352 and locker warp yarns 353.

We claim:

1. A thick-walled, seamless and tubular article comprising an integrally woven fabric being woven about a given axis, said fabric comprising locker warp yarn systems and a continuous helical filling yarn system, said filling yarn system comprised of continuous filling yarns forming a plurality of annular and substantially parallel yarn planes being concentric and coextensive with said axis and said locker warp yarn systems com-

prising of locker warp yarns forming locker warp yarn planes arranged coextensively and radially with respect to said axis, said locker warp yarns within a given one of said locker warp yarn planes traversing a plurality of said filling yarn planes and locking said filling yarns together by following a predetermined sinuous path.

2. A thick walled article comprising an integrally woven thick fabric, said fabric being woven in the configuration of a predetermined three-dimensional form and comprising first, second and third yarn systems positioned about a reference axis, said first yarn system being comprised of locker warp yarns forming locker warp yarn planes arranged coextensively and radially with respect to said axis, said second yarn system being comprised of filling yarns forming filling yarn planes arranged concentrically and coextensively with said axis, said locker warp yarns within a given one of said locker warp yarn planes traversing a plurality of said filling yarn planes and locking said filling yarns together by following a predetermined sinuous path and said third yarn system being comprised of stuffer yarns forming stuffer yarn planes arranged coextensively and radially with respect to said axis, said stuffer yarn planes traversing a plurality of said filling yarn planes.

3. The thick-walled articles of claim 2 wherein said yarn planes occupied by said locker yarns sequentially alternate with said yarn planes formed by said stuffer yarns.

4. The thick-walled article of claim 2 wherein said three-dimensional shaped is continued uninterruptedly about the said axis.

5. The thick-walled article of claim 4 wherein the individual picks of said filling yarns lie in yarn planes normal to said axis, said yarn planes being substantially parallel to each other.

6. The thick-walled article of claim 5 wherein said locker warp yarn planes and said stuffer warp yarn planes are radially arranged with respect to and include said axis.

7. The thick-walled article of claim 6 wherein the angle between a plane which is tangent to the surface of said thick-walled article and the said axis of the said thick-walled article is greater than 0 degrees and less than 90 degrees.

8. The thick-walled article of claim 7 wherein the number of said locker warp yarn planes and said stuffer warp yarn planes comprising said first and third yarn systems varies along the axis of said fabric so that as the distance between said thick-walled article surface and said axis fluctuates a uniform fabric density is maintained.

9. The thick-walled article of claim 6 wherein said fabric includes an inner and an outer surface and wherein each of the locker warp yarns diagonally traverses selected ones of said filling yarn planes reciprocating between said inner and outer fabric surfaces within said locker warp yarn planes radially disposed with respect to said axis.

10. The thick-walled article of claim 9 wherein the number of locker warp yarns comprising a given plane at least equals the number of filling yarn picks comprising a filling yarn deck having been traversed by said locker yarn plane.

11. The thick-walled article of claim 10 wherein the number of stuffer yarns comprising a given plane is less

than the number of filling yarn picks comprising the filling yarn deck having been traversed by said given stuffer yarn plane.

12. The thick-walled article of claim 2 wherein said filling yarn picks are circumambiently positioned about said axis.

13. The thick-walled article of claim 12 wherein said stuffer yarn planes and said locker yarn planes are radially disposed with respect to and include said axis and which in combination with said filling yarn planes form a fabric having irregular cross-sectional dimensions.

14. The thick-walled article of claim 13 wherein the number of locker yarn planes and stuffer yarn planes traversing selected filling yarn planes varies along the axis of said fabric proportionally with the distance between said selected filling yarn planes and said axis to maintain a uniform fabric density.

15. The thick-walled article of claim 12 wherein said predetermined three-dimensional shape is a cylinder.

16. The thick-walled article of claim 12 wherein said predetermined three-dimensional shape is a truncated cone.

17. The thick-walled article of claim 12 wherein said predetermined three-dimensional shape is a hyperboloid of revolution of one sheet.

18. The thick-walled article of claim 12 wherein said predetermined three-dimensional shape is a truncated paraboloid of revolution.

19. The thick-walled article of claim 12 wherein said fabric includes inner and outer surfaces and wherein said locker yarns comprising said locker yarn planes extend reciprocally from said inner surface to said outer surface to encompass the outermost lying and the innermost lying of said filling yarns forming a given deck whereby the filling yarn deck integrity is maintained.

20. A thick walled substantially rigid fabric comprising a plurality of integrally combined yarn systems each of which includes a plurality of yarn planes spatially arranged about a reference axis, the yarn planes of a first

yarn system being parallel to each other and normal to said axis, the yarn planes of a second yarn system being radially aligned with respect to said axis, the yarns of said second yarn planes traversing and interlocking the yarns of said first yarn planes to maintain the integrity of said first yarn system and the yarn planes of a third yarn system being radially aligned with respect to said axis and traversing said yarn planes of said first yarn system.

21. The shaped fabric of claim 20 wherein the yarn planes of said third yarn system alternate in sequence with said yarn planes of said second yarn system.

22. The shaped fabric of claim 21 wherein said fabric is substantially free of localized stress areas.

23. The shaped fabric of claim 22 wherein said fabric has a uniform fabric density.

24. The shaped fabric of claim 22 wherein said fabric has a non-uniform fabric density.

25. The shaped fabric of claim 21 wherein said fabric has a uniform fabric density.

26. The shaped fabric of claim 21 wherein said fabric has a non-uniform fabric density.

27. The shaped fabric of claim 23, said fabric defined by inner and outer surfaces and wherein the yarns comprising said yarn planes of said second yarn system lie in paths reciprocating between said fabric inner and outer surfaces.

28. The shaped fabric of claim 24, said fabric defined by inner and outer surfaces and wherein the yarns comprising said yarn planes of said second yarn system lie in paths reciprocating between said fabric inner and outer surfaces.

29. The shaped fabric of claim 27 wherein said yarns of said first yarn system are circumambiently positioned about said axis.

30. The shaped fabric of claim 28 wherein said yarns of said first yarn system are circumambiently positioned about said axis.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,719,212 Dated March 6, 1973

Inventor(s) PAUL D. EMERSON, ET. AL.

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

On the cover sheet [75], "John C. Oakfield" and
"Charles E. Barter" should read -- John C. Oatfield -- and
-- Charles E. Bartee -- . On the cover sheet [73],
"Barter" should read -- Bartee -- .

Signed and sealed this 20th day of November 1973.

(SEAL)

Attest:

EDWARD M. FLETCHER, JR.
Attesting Officer

RENE D. TEGTMEYER
Acting Commissioner of Patents