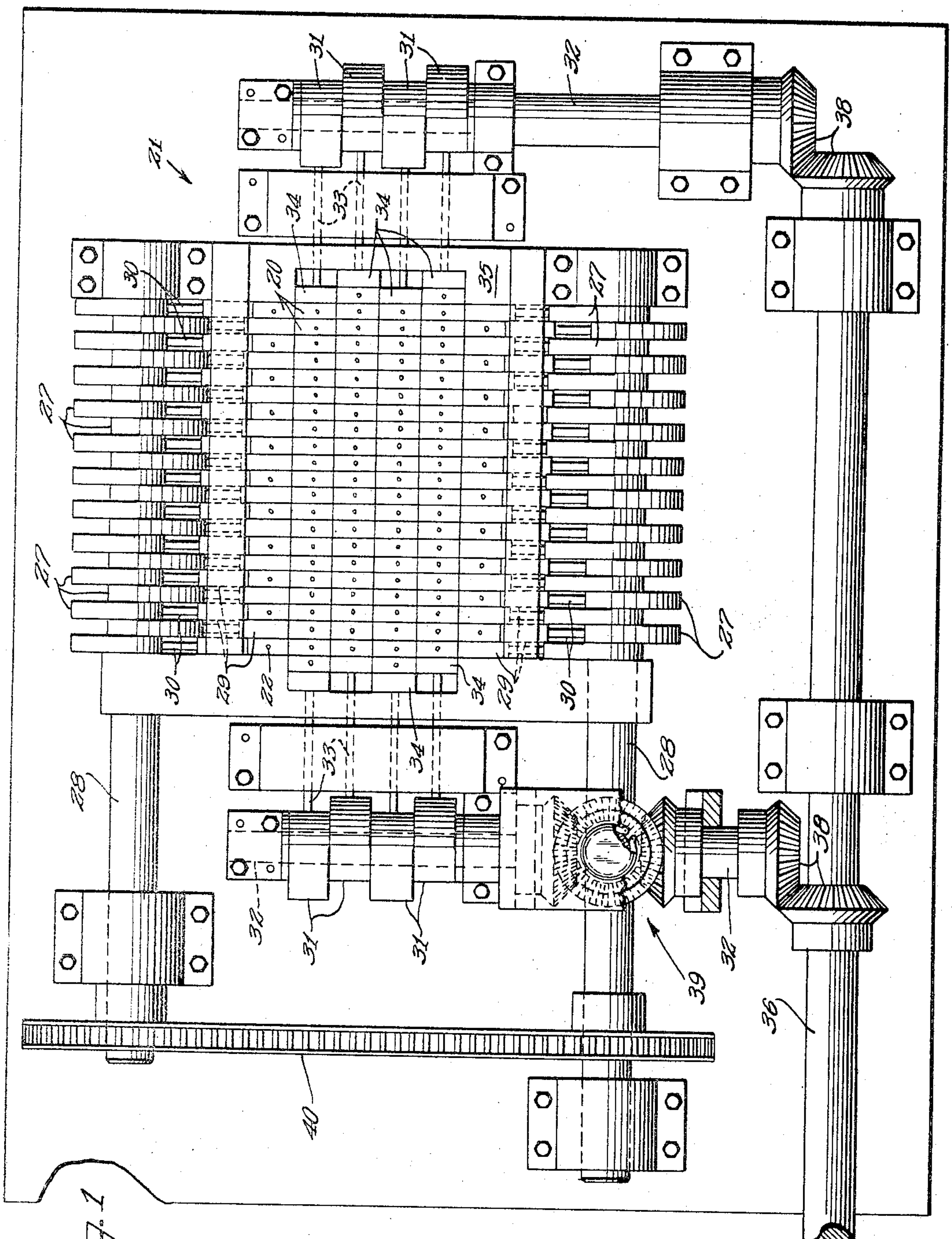

Fig. 1

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HIGH SPEED BIAS WEAVING AND BRAIDING

Filed Dec. 20, 1966 Sheet 2 of 7

Fig. 2

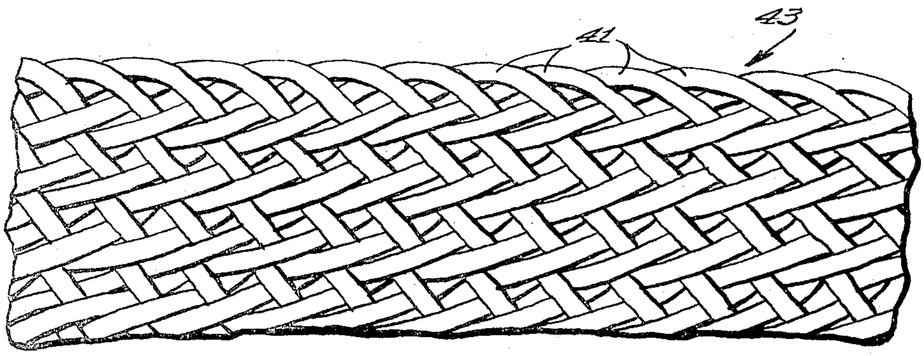
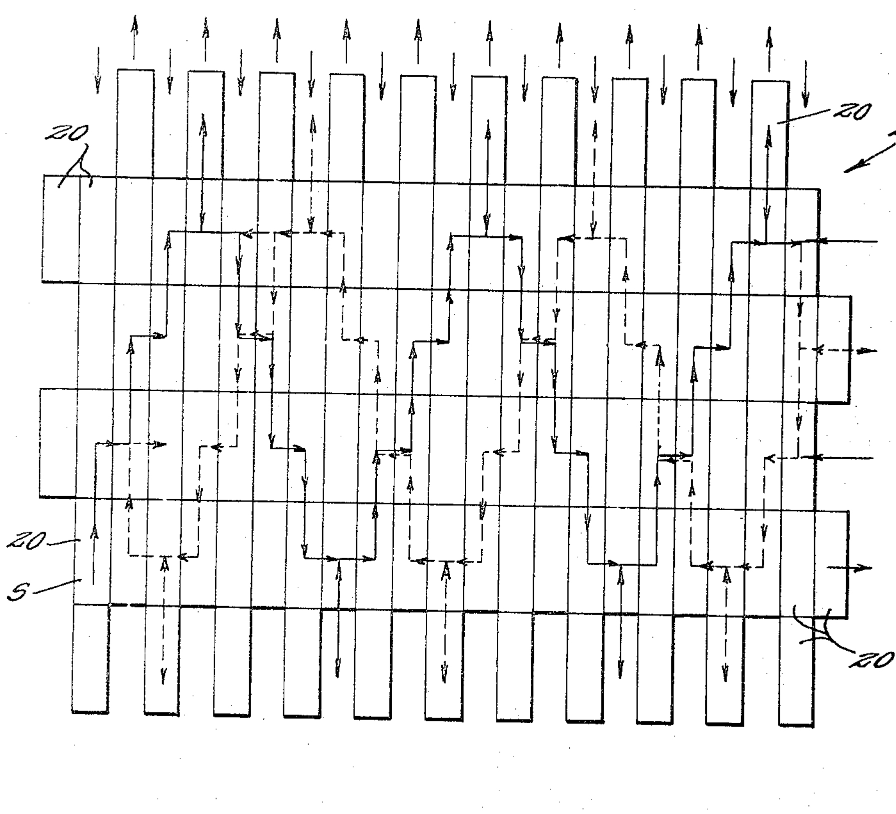


Fig. 3



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HIGH SPEED BIAS WEAVING AND BRAIDING

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Fig. 4

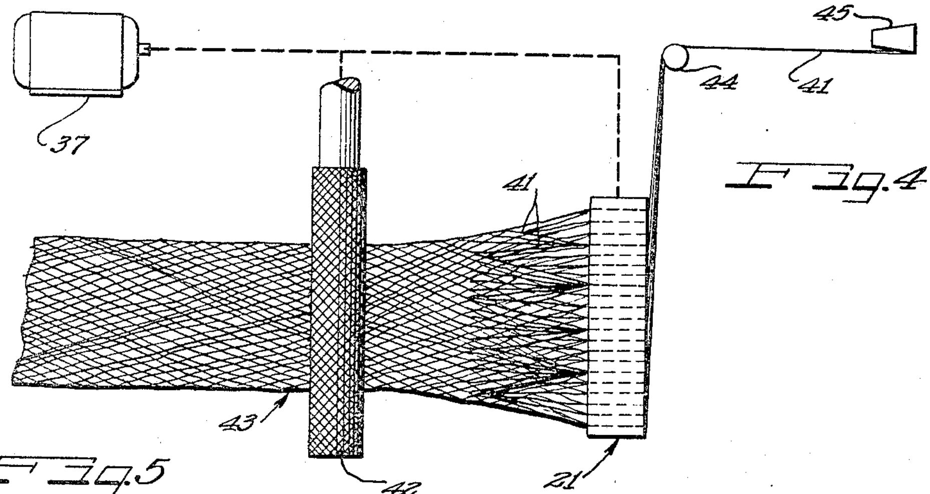


Fig. 5

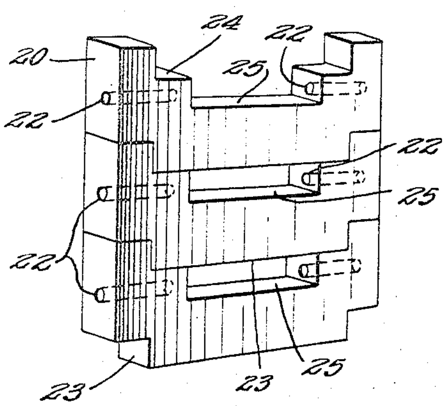


Fig. 7

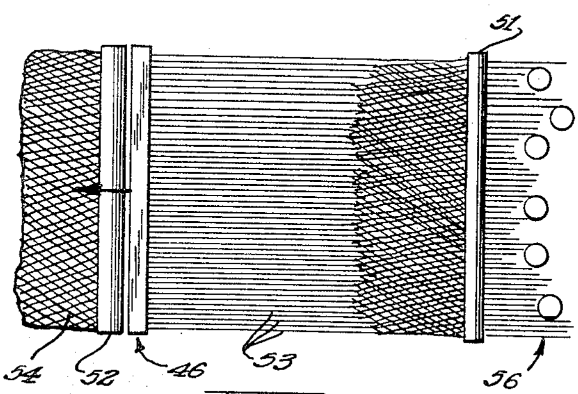
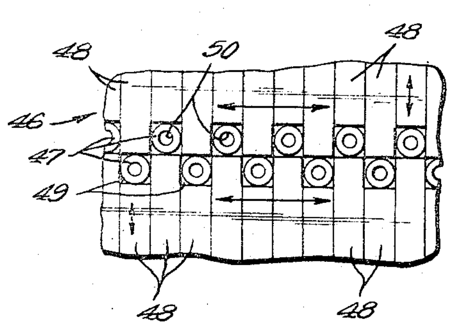
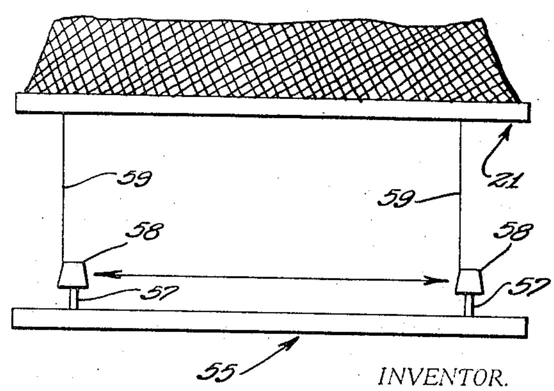


Fig. 8

Fig. 6





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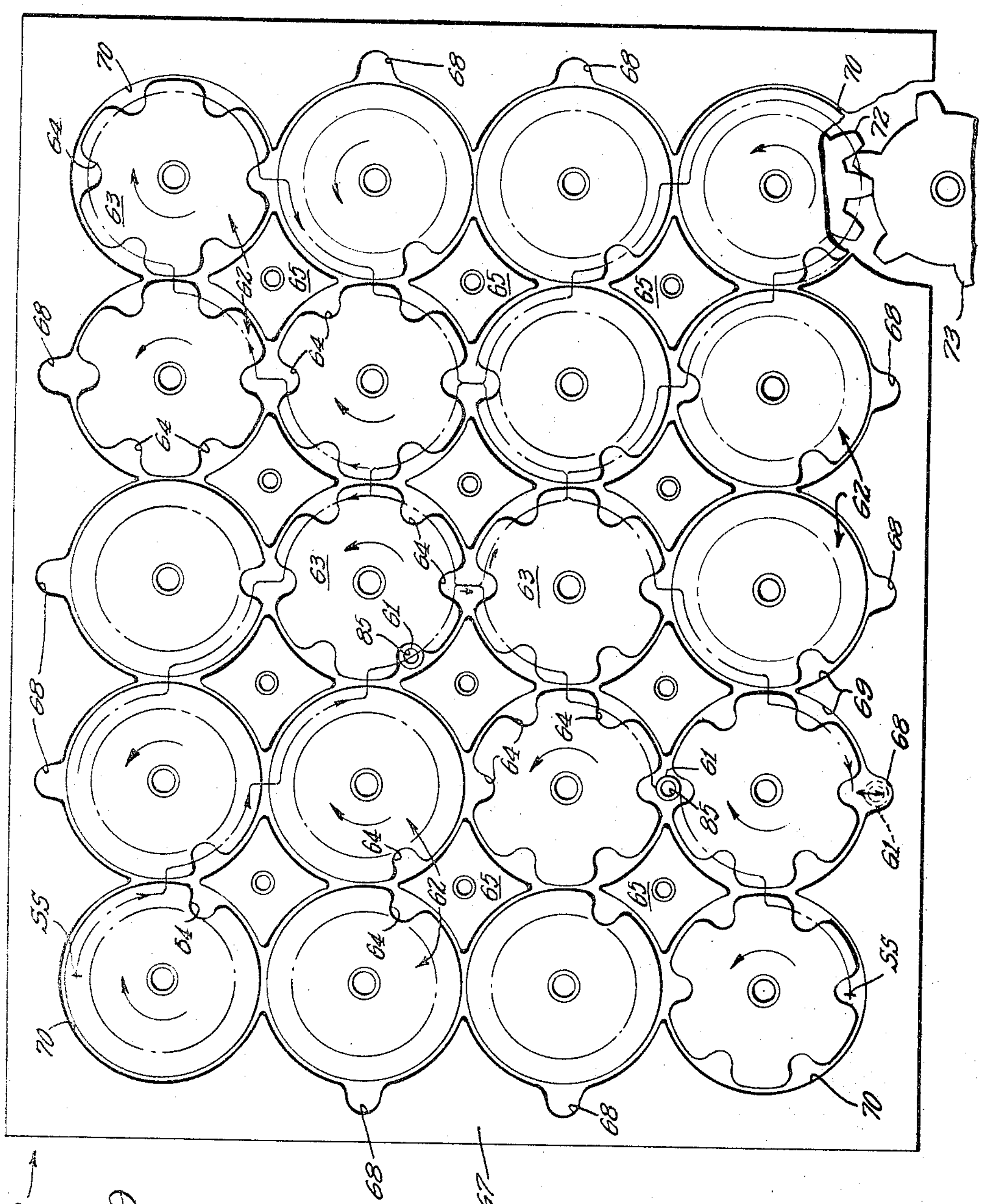

Fig. 9

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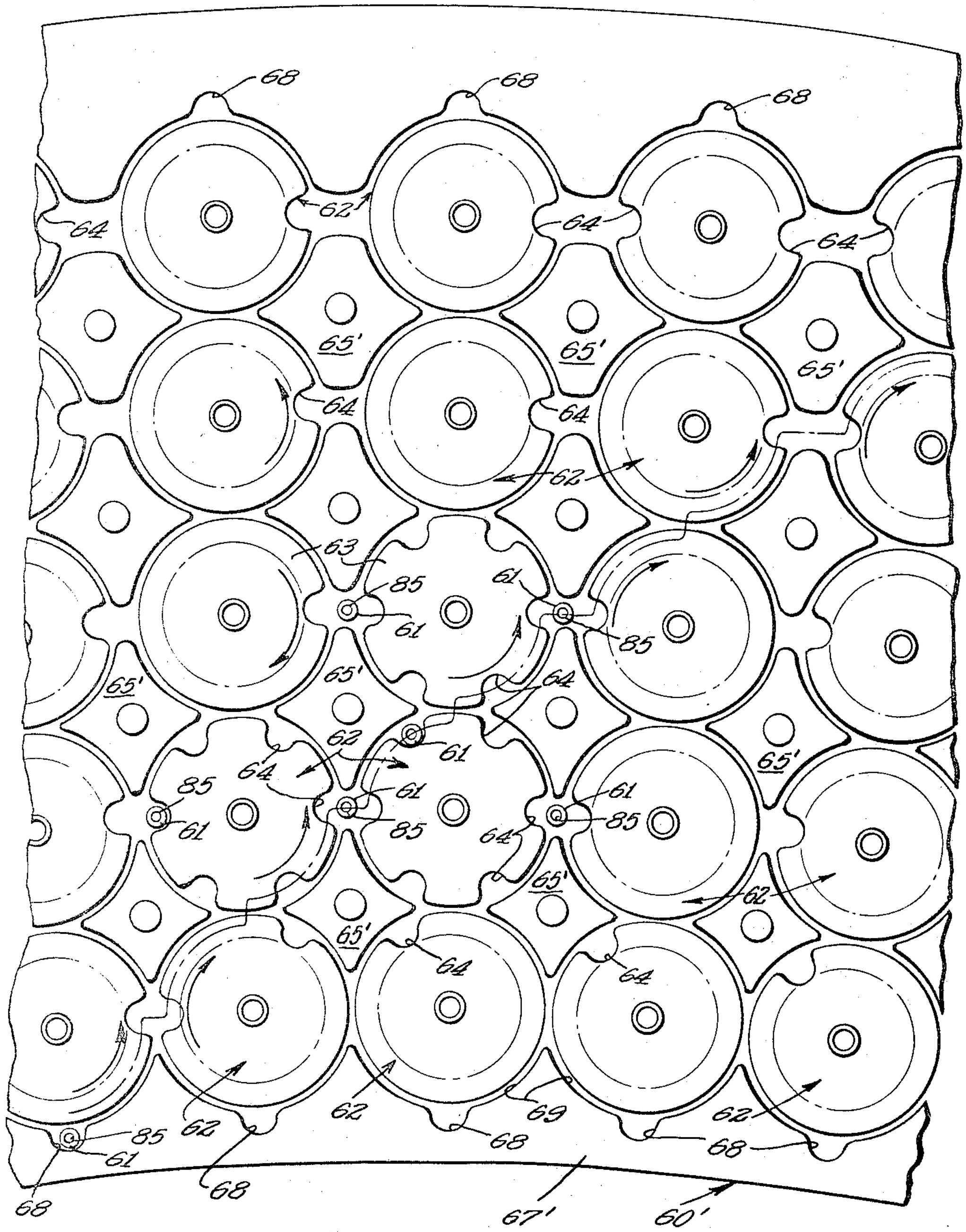

Fig. 10

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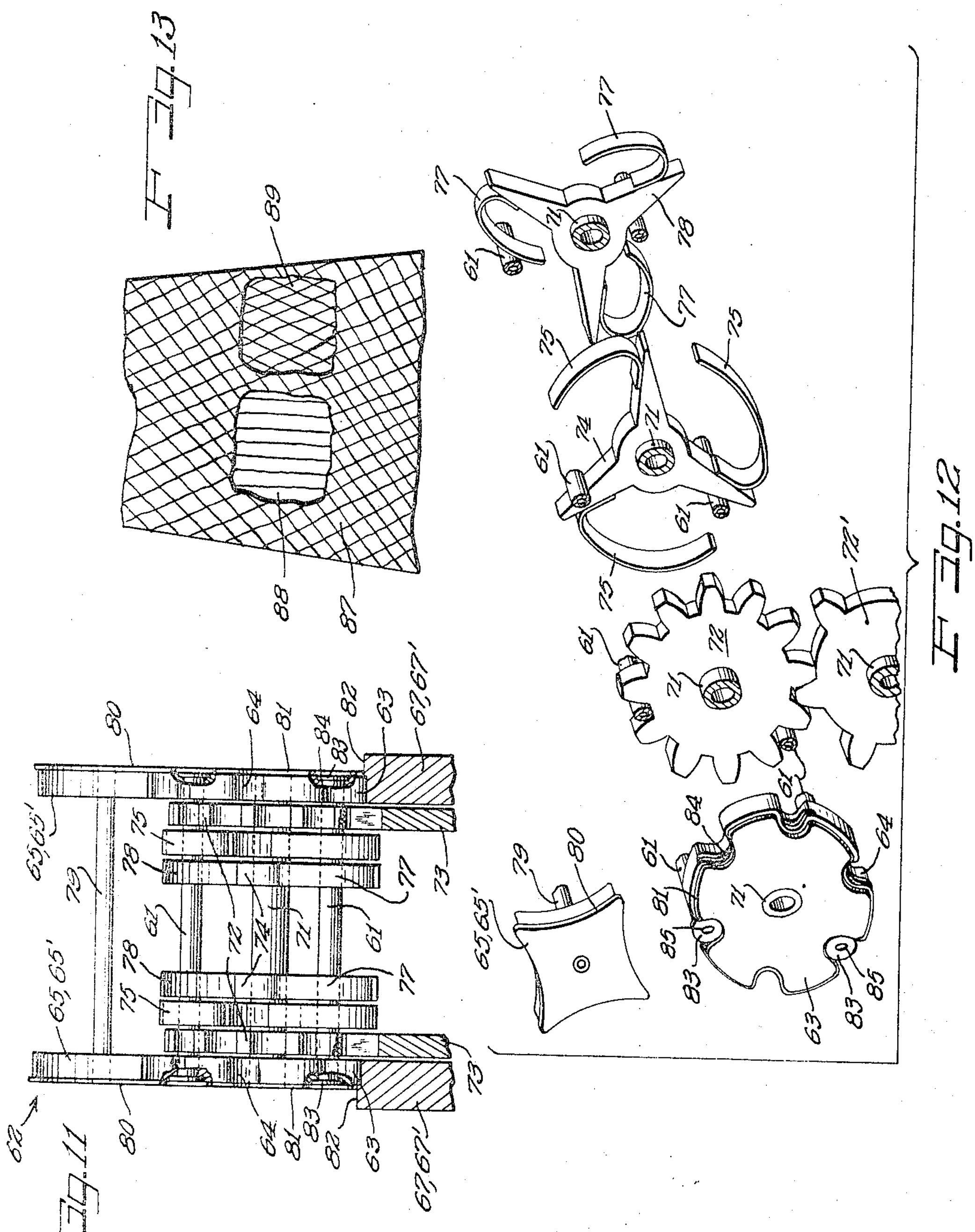

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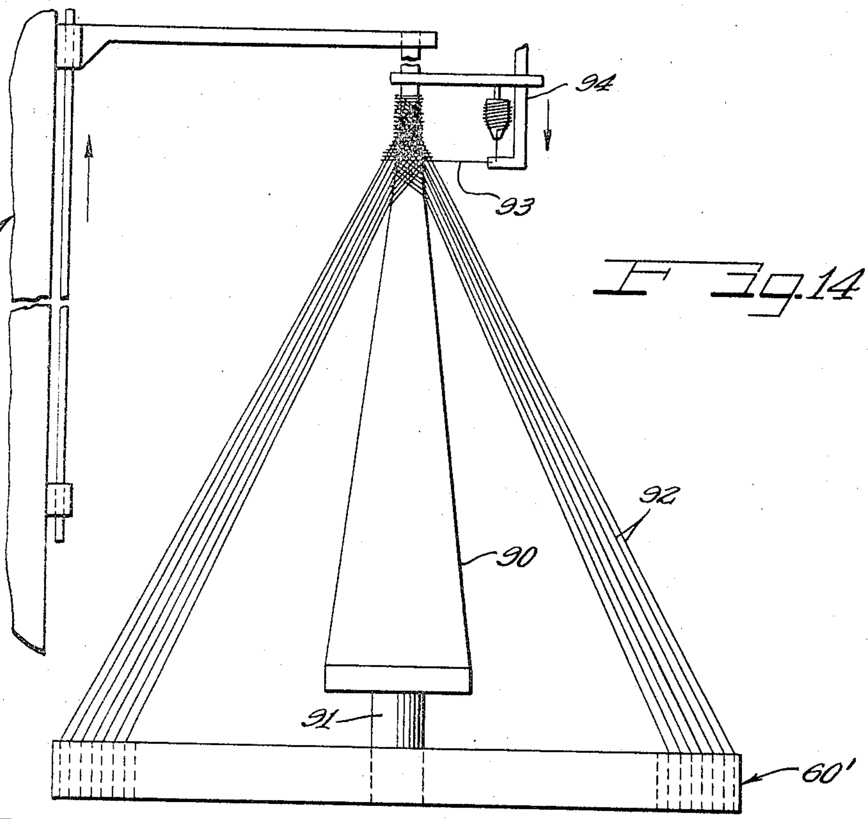


Fig. 14

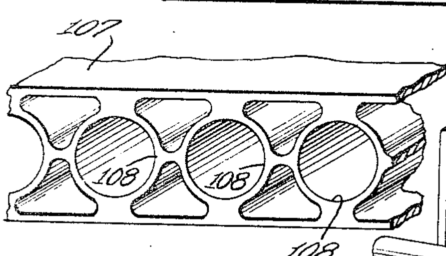
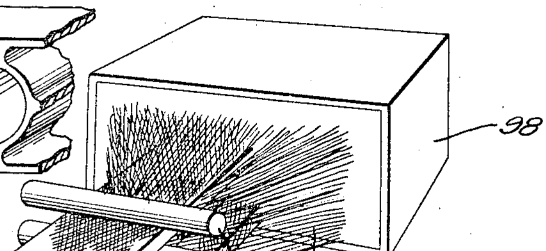
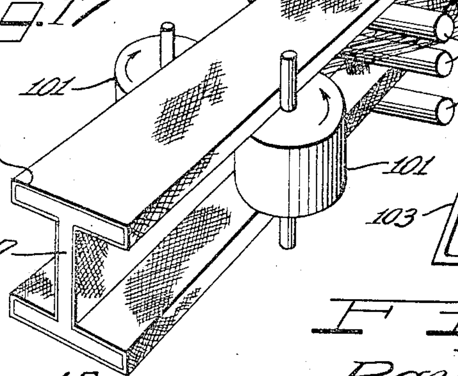


Fig. 17





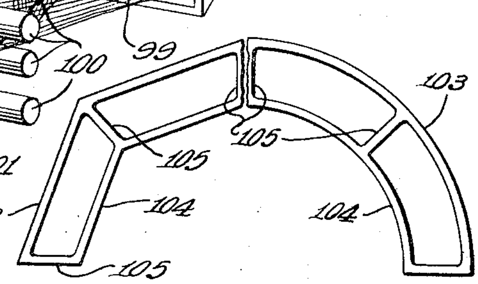


Fig. 16

Fig. 15

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HIGH SPEED BIAS WEAVING AND BRAIDING

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Filed Dec. 20, 1966, Ser. No. 603,304
U.S. Cl. 139—11 19 Claims
Int. Cl. D03d *49/20, 41/00;* D04c *5/06*

ABSTRACT OF THE DISCLOSURE

Continuous high speed bias weaving and braiding, with or without longitudinal weaving elements, and with the angle of the bias elements extending selectively from nearly perpendicular to nearly parallel to the weaving direction. Each bias element runs through an individual mobile guide member in a nest of such members cooperatively controlled to follow given weaving pattern paths.

This invention relates to the art of bias weaving and braiding, and is more particularly concerned with greatly increasing the speed and versatility of such weaving and braiding, utilizing yarns, threads, filaments, and the like as the bias elements in the production of a wide variety of fabrics and shapes.

Conventionally, weaving of broadgoods fabric, with both soft and harder types of weaving elements, has been effected with shuttle loom or traversing arm types of equipment. Such equipment has been developed and refined to the substantially ultimate limits of acceleration, machine cycle reliability, weaving element strength, etc.

In the production of internally pressurized vessels, ablative heat shields, and the like, various structural shapes, and the like, filament winding, complex warp and fill loom weaving, laminated configurations, tape wrapping using joined cut strips, and the like, have been employed.

Necessarily slow production speeds, expenditure of labor and materials, and the like, have resulted in excessively high cost, while limitations of capability of conventional equipment and performance restrictions of the fabrics produced have seriously limited usefulness as well as the reliability of the end structure.

Accordingly, an important object of the present invention is to overcome the foregoing and other problems and disadvantages of the prior art and to provide a new and improved method of and means for producing woven and braided articles from yarns, threads, filaments, and the like.

Another object of the invention is to provide a novel method of and means for high speed bias weaving and braiding of fabrics with the bias weave angle variable from nearly perpendicular to the direction of weaving to nearly parallel to the direction of weaving, and where desirable including elements parallel to the direction of weaving, with variable frequency across the width, as desired or required, and including broadgoods fabrics to be used in all forms of commercial soft goods, structural glass fabrics for use as matrix with suitable binder in the production of structural shapes, pressurized vessels, ablative structures, and the like.

A further object of the invention is to provide a new method of and means for high speed bias weaving and braiding.

Other objects, features and advantages of the present invention will be readily apparent from the following detailed description of certain preferred embodiments thereof taken in conjunction with the accompanying drawings, in which:

FIGURE 1 is a generally schematic elevational view of a representative machine for bias weaving, embodying principles of the present invention;

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FIGURE 2 is a fragmentary detail plan view of a piece of bias woven fabric as produced by the machine of FIGURE 1;

FIGURE 3 is an illustrative elevational view of the bias element or thread guide nest of the machine of FIGURE 1 demonstrating, by way of example, certain weaving element guide traveling sequences or predetermined running patterns;

FIGURE 4 is a schematic plan view of the weaving setup of the machine of FIGURE 1;

FIGURE 5 is a perspective view of representative thread guide members as used in the machine of FIGURE 1;

FIGURE 6 is a fragmentary plan view of a modified form of thread guide nest;

FIGURE 7 is a schematic plan view of a weaving scheme which may employ the thread guide nest of FIGURE 6;

FIGURE 8 is a schematic plan view showing a weaving scheme according to the invention embodying the use of thread spools which are movable relative to the guide nest;

FIGURE 9 is a schematic elevational view of another modified thread guide nest arrangement;

FIGURE 10 shows the adaptation of the guide nest arrangement of FIGURE 9 to a rotating drum;

FIGURE 11 is a fragmentary side elevational view showing one of the guide transfer rotors as employed in the guide nests of FIGURES 9 and 10;

FIGURE 12 is an exploded assembly view of the guide transfer rotor;

FIGURE 13 is a fragmentary schematic illustration exemplifying a three orientation pattern attainable simultaneously in a cone shape pursuant to the present invention;

FIGURE 14 is a fragmental schematic side elevational view illustrative of braided cone weaving pursuant to the present invention and utilizing a rotary drum weaving nest on the order of that exemplified in FIGURE 10;

FIGURE 15 is a schematic perspective view illustrating structural shape weaving according to the present invention;

FIGURE 16 is a schematic end elevational view of a double skin, web reinforced shape produced according to the present invention; and

FIGURE 17 shows in fragmentary perspective a further representative structural shape attainable according to the principles of the present invention.

According to the new method of the present invention, bias weaving or braiding is effected by moving a plurality of individual weaving elements into one end of and through respective guide eyes of individual guide members and beyond the opposite ends of the eyes crossingly interengaging the elements into an article. The order of crossing interengagement of the elements is attained by relatively cooperatively moving the guide members in a predetermined weaving or braiding pattern within a plane generally normal to the weaving or braiding direction and comprising directing the guide members to follow generally zig-zag respective crossing paths and thereby orienting the elements in over and under crossing interwoven relation while withdrawing the elements from said opposite ends of the eyes continuously into the article.

One representative form of apparatus for practicing this method for the production of broadgoods fabric such as various forms of commercial soft goods, structural glass fabrics, and the like, is depicted in FIGURES 1, 3, 4 and 5. This comprises individual guide member **20** slidably cooperatively related in perpendicularly oriented rows in a nest **21** within which the elements are movable according to a predetermined pattern to travel from row to row in a weaving plane substantially perpendicular to the weaving direction. In one practical form, the elements **20** comprise identical generally rectangular blocks constructed to nest with one another. Each of the guide member blocks has therethrough a weaving element eye **22** comprising a bore of a diameter to receive the desired diameter of weaving or braiding element freely therethrough with minimum frictional resistance while running at high speed in operation from the entry end at the back face of the guide member to and from the exit end at the front or weaving face of the guide member. In the illustrated form, each of the guide members **20** is of narrow form between its parallel flat sides, is elongated in a front to rear direction and has opposite longitudinal edges which are configurated for internesting cooperation with companion members **20** in the nest, including a lug **23** along one edge suitably spaced from the opposite ends of the member, and a complementary tracking recess **24** in the opposite edge of the member. If desired, passage friction through the eyes **22** may be minimized by a sub-recess **25** extending inwardly from the tracking recess **24** and intersecting the eye **22** in each instance and affording a free space between the opposite axially aligned spaced portion of the thus divided guide eye.

Because of the tracking interengagement of the guide members **20**, they mutually retain one another against displacement from the weaving plane but permit ready operative individual, tracked shifting of the individual members in predetermined weaving patterns as is conveniently effected by sequentially slidably shifting the guide members **20** from row-to-row in both directions within the weaving plane. Means for this purpose conveniently comprise respective cams aligned with the rows of guide members. As represented in FIGURE 1, complementally cooperative disk cams **27** are mounted on respective cam shafts **28** to operate through pusher blocks **29** complementary to and engaging in the complementary slidable tracking relation with the edges of the respective guide members at any given time along the edges of the nest **21** defined by the guide member edges. Suitable follower rods or stems **30** on the respective pushers **29** engage the cam edges of the sets of cams **27**. To similar effect, respective sets of complementary disc cams **31** mounted on respective cam shafts **32** are drivingly engaged by follower stems or rods **33** extending from side face pusher blocks **34** aligned with and engaging the respective side endmost of the guide members **20** in slidable tracking relation. Operating containment of the weaving guide nest and guiding of the follower stems **29** and **33** is effected by a suitable supporting frame structure **35**. The respective cam settings determine the order of shifting of the respective rows of guide members. In the example shown, including twenty-two rows from side-to-side by five from edge-to-edge and one row in each direction alternately extended along the respective opposite edges of the nest (FIGS. 1 and 3), the orientation is such as to drive the edgewise rows alternately oppositely between alternate opposite shifting of the sidewise rows of guide members **20** and thereby effect timing dwell of these members respectively as the direction of travel is changed in their paths. Coordinated operation of the several sets of guide member shifting cams is effected in any suitable manner such as by means of a common driveshaft **36** deriving its power from a suitable power source such as an electrical motor **47** (FIG. 4). Means such as bevel gears **38** operatively connect the shaft **35** with the respective cam shafts **32**. Bevel gears **39** operatively connect one of the cam shafts **32** with one of the cam shafts **28** which is drivingly connected as by means of a flexible chain or belt **40** and suitable pulleys with the remaining cam shaft **28**.

As the respective transversely arranged rows of guide members **20** are shifted, as driven by the respective sets of cams, each individual one of the guide members **20** travels a predetermined weaving path in the weaving plane. In FIGURE 3 the path traveled by one of the guide members **20** beginning at the starting location S is traced by a directional continuous solid arrow line from one side to the opposite side of the nest **21** and then by a dashed directional arrow line to the nearest return position relative to the starting position S. The path that will be followed by each of the numerous guides **20** may be similarly traced. Eventually, after a plurality of cycles of travel, the member **20** whose path has been specifically delineated in FIGURE 3 will return to the same starting position S to repeat its sequence of cycles. This is true, also, of each other of the guide members **20**.

Through the described arrangement, continuous, high speed weaving is accomplished, with individual weaving elements **41** (FIGS. 2 and 4) moving at a continuous common speed as the guides **20** through which the individual elements travel respectively move sequentially in the weaving plane across the weaving direction and at a weaving rate determined by opposed take-off rollers **42** between which the woven fabric is gripped and drawn away from the weaving face of the guide nest **21**. Schematically the rollers **42** are shown as having suitably knurled perimeters for non-slip frictional gripping of the fabric **43**, but a non-slip rubber or other perimeter may be provided if preferred. Driving of the rollers **42** is adapted to be accomplished in coordinated relation to the guide nest **21** by suitable drive connection, gearing, etc., from the same source of power such as the electric motor **37**, as a desirable arrangement.

Backweaving or tangling of the numerous individual weaving elements **41** at or in advance of the back face of the weaving guide nest **21** is avoided, in one desirable manner by feeding the weaving elements to the guide members in a direction across the weaving direction, and more particularly in a plane which is as nearly as practicable parallel to the weaving plane, as indicated in FIGURE 4. Approach of the weaving elements to the back face of the nest **21** is controlled by guide means such as a bar or roller **44** after the elements leave their supply source such as spools **45** or the like which may thus be mounted in stationary position. Through this arrangement, the weaving elements **41** freely pass one another at the back face of the nest **21** and avoid any cross-over relative to one another. Suitable tensioning means may be provided, as is customary, in the feed path of the weaving elements **41** to the back face of the nest **21** and more particularly before the weaving elements reach the guide means **44** to avoid slack in the passing plane for the weaving elements from the guide means **44** to the back face.

Variations in weaving pattern, number of weaving elements employed, widths, thickness, density or looseness of weave, the order of over and under orientation of the weaving elements, the bias weaving angle, and the like, may be widely varied by selection of the material of the weaving elements, weaving element diameter selection, number of weaving elements employed, travel paths predetermined for the guide members, distance of the takeoff rollers **42** from the guide nest **21**, etc.

In another form of generally rectangular nest **46** guiding of the weaving elements, as represented in FIGURE 6, tubular thread guides **47** are employed which are controlled in movement by means of transfer blocks **48** defining therebetween guide member pockets **49**. Each of the tubular guide members has a weaving element guide eye **50** axially therethrough. In operation, the transfer blocks **48** have a predetermined cooperative reciprocation sequence effected in any suitable manner, such as by means of sets of cams, whereby, for example, the guide members **47** progress in a desired sequence across the nest from side-to-side. For example, the transfer blocks **48** in the series along the edge of the set of guide transfer pockets **49**, herein those in the upper portion of FIGURE 6, may have merely alternately oppositely reciprocating action, with corresponding alternately opposite reciprocating action of the opposed transfer blocks **48**. However, the opposite set or series of transfer blocks **48**, namely those in the lower portion of FIGURE 6, have, in addition, a side-to-side reciprocating shifting movement in unison in operation, coordinated in any preferred sequence between mutual reciprocations of the opposed sets of transfer blocks. For example, while the upper row, as shown, of the transfer blocks **48** may have only up and down reciprocal movement, the lower row of the transfer blocks **48** has the corresponding up and down reciprocating movement, and also has left to right reciprocating movement which may comprise a two space shift toward one side succeeded by a two space shift toward the opposite side, cyclically. Although only one staggered row of the tubular thread guides **47** is shown, there may be as many such rows as desired in any given weaving guide nest, depending on the character of the woven article desired. Among the advantages of this form of guide nest, is that the rolling tubular thread guides may operate with possibly less close tolerances than the stacked arrangemnet of guide member blocks in the FIGURE 1 form.

Although the tubular thread guide nest **46** may be supplied with weaving elements in the same manner as described in connection with FIGURE 4, namely, in a path along the back face of the nest across the weaving path, this arrangement also lends itself to straight infeed from a fixed creel **56** (FIG. 7) through tension rolls **51** spaced a substantial distance from the back face of the weaving guide nest and with takeoff rolls **52** located as close as practicable to the weaving face of the nest. Through this arrangement, weaving of elements **53** by straight infeed to the weaving guide nest **46** progresses by alternate periods of weaving and reversing of the operation of the weaving guide nest. During the weaving intervals back weaving of the elements **53** occurs between the weaving guide nest **46** and the tension rolls **51** and unweaving is effected by the reverse operation of the weaving guide nest. Reversing the cyclic guide movement by missing one vertical shift reverses the left to right movement for all guides. The reversed cycle continues until the back unweaving is completed and it is then reversed again. Weave take-off runs continuously with the take-off roll being the contact point for effective weaving precluding unweaving in the fabric direction. The resulting fabric **54** will show a double length weave and reversal in fiber direction. This variation properly spaced along the length of fabric should not be undesirable.

In another manner of feeding weaving elements to the guide nests **21** or **46** (FIG. 8) a spigot creel **55** facing the backface of the weaving guide nest and equipped with spigots **57** carrying respective spools **58** from which individual weaving elements **59** are fed to the weaving guide nest. The spigot creel **55** may be of the rotating drum type and with the spigots arranged to deliver the weaving elements in coordinated relation with movement of the respective thread guide members in their operative travel in the guide nest, whereby to avoid any back weaving and enabling continuous weaving, at least to the limit of thread or other weaving elements supplied. If preferred, the spigots **57** may be operated according to the conventional figure-8 pattern in which the creel **57** remains stationary or rotates, as preferred and the spigots follow a pattern of respective cyclical travel on the creel corresponding to movements of the guide members of the guide nest in a manner to avoid backweaving during continuous bias weaving.

In the modification of FIGURE 9, a thread guide nest **60** of generally rectangular form adapted for production of bias woven flat goods is represented employing tubular guides **61**, on the order of the tubular guides **47** of FIGURE 6, but controlled to travel predetermined weaving paths by means of rotary guide transfer devices **62** including respective face disks **63** having peripheral transfer notches **64** in a preferred equally spaced series. Concavely edged retaining and spacer disks **65** oppose the perimeters of each respective cluster of four of the face disks **63** and cooperate therewith in transfer of the thread guides **61** from transfer device to transfer device **62** in the operation of the guide nest. The transfer devices **62** are maintained by the spacer disks **65** and a supporting frame **67** in crossing parallel rows. Although only two of the thread guides **61** are shown, it will be understood that each of the transfer devices **62** will at any given time have in transport association therewith one of the thread guides in every alternate one of the six indentations **64**, with the intervening indentations correlated with the companion transfer devices to receive respective tubular guide members **61** for transfer from transfer device to transfer device progressively along the predetermined cyclical weaving path of each given guide member. By way of example, the respective paths which may be followed by the two representative tubular guide members **61** starting at respectively the starting points SS are indicated by directional progress lines on FIGURE 9, showing that the guide members travel from one corner of the nest to the opposite corner of the nest and return. Each other of the guide members **61**, though not individually shown, will similarly travel a predetermined weaving path correlated to the weaving travel path of every other guide member in the nest. Associated with each of the transfer devices **62** intervening between the corner units of such transfer devices, is a respective squence or timing slot, notch or indentation **68** provided in the supporting frame **67** to effect a dwell in the respective guide members **61** at the midpoint in traveling along respective and generally semi-cylindrical guide surfaces **69** provided by the frame for the associated devices **62**. This provides for a one-step dwell in the advance of each guide member **61** during turnabout or change of direction of travel from the edges or sides of the nest. Turnabout at the corners of the nest attains the same result by greater distance of travel afforded by longer semi-cylindrical transfer guide surfaces **70** on the frame **67** for the affected transfer devices **62**.

In the modification of FIGURE 10, a weaving guide arrangement employing the same principles is depicted, comprising a guide nest **60'** of rotating drum shape employing a guide frame **67'** which may conveniently be of generally annular disk drum configuration carrying the rotary transfer devices **62** in radial and annular rows continuously thereabout and with the radial rows slightly divergently related on the radius, with the spacer disks **65'** progressively slightly larger from the inner toward the outer diameter of the nest of the drum to compensate for such divergence. In other respects the transfer devices **62** and the tubular thread guide members **61** are the same as in FIGURE 9 and are thus similarly numbered and the description need not therefore be repeated either as to structural or function and will be understood to be the same and apply equally in respect to FIGURE 10 as to all features having the same reference numerals.

A desirable construction of the guide transfer devices **62** is more particularly shown in FIGURES 11 and 12. Each is in the form of a self-contained rotor comprising a shaft **71** on the opposite end portions of which are mounted respective identical, but reversely assembled, fixedly attached sets of transfer elements, each including as its outer end member one of the peripherally indented facing disks **63**. Inwardly contiguous to each of the facing disks **63** is mounted a 12-toothed driving gear **72** or a 6-toothed driving gear **72'** so aligned with the associated facing disk that every other gear tooth notch or space is aligned with one of the six disk notches **64** in the 12-tooth gear and between each pair of teeth in the six-tooth gear, whereby to accommodate the tubular thread guides **61** without interference although the 12-tooth gears **72** on alternate ones of the guide transfer rotors in the nest mesh drivingly with the six-tooth gears **72'** of their neighboring alternate transfer rotors. Thereby all of the rotors are driven in unison as by means of one or more driving gears **73** (FIGS. 9 and 11) suitably mounted on or in association with the supporting frame **67, 67'** to mesh drivingly with the adjacent transfer rotor driving gear and deriving power from any suitable source desirable for driving the machine.

Inwardly contiguous to the driving gear is fixedly mounted a three-pronged star wheel **74** mounting respective spring trip pawl cams **75** cooperatively related to the transfer indentations **64** of the disks **63** and to respective spring trip pawl cams **77** mounted on the arms of a second three-arm star wheel **78** fixedly mounted inwardly contiguous to the wheel **74** and indexed with the respective sets of arms suitably relatively offset. Through this arrangement, tubular thread guides **61** are transferred from rotor to rotor at tangency alignment of transfer indentations **64** by action of the springs **75** and **77**. Timing is easily effected by proper indexing and matching of the star wheels **74** and **78** of the respective transfer rotors.

Retention of the guide transfer rotors against both longitudinal and transverse displacement from respective operative position is precluded by the cooperative relation of the spacer disks **65, 65'** and the supporting frame **67, 67'**. For this purpose the spacer disks **65, 65'** are provided in axially spaced pairs matching the guide transfer rotor construction and each pair of spacer disks fixedly mounted on a connecting rod **79**. A sliding tongue and groove axial retaining connection is provided as by having respective retaining tongue flanges **80** along the outer sides of the sliding edges on the spacer disks engaging in an outer marginal peripheral groove **81** in the associated transfer disks **63**. Further, the frame **67, 67'** has a matching retaining tongue flange **82** along each of the respective guide edges **69** and **70** slidably engaging in the respective grooves **81**. The tubular thread guides **61** have on their respective opposite ends retainer flanges **83** which are received in outer marginal grooves **84** aligned with the respective transfer indentations **64** and clear of the respective grooves **81**, whereby the thread guide members are held against against axial displacement while permitting free transfer thereof from rotor to rotor in the operation of the guide nest. Through this arrangement reasonable tolerances between relatively moving parts is permitted while nevertheless all parts are properly integrated in all relative positions during cyclical guiding of the thread guides **61** in their weaving paths, and both the back and weaving faces of the weaving nest **60, 60'** are maintained entirely clear and free of any obstruction to free access of weaving elements for entry into and for weaving exit from respective eyes **85** extending through the tubular guide members **61**. Although there is actual cooperative physical contact between the various elements, as is shown in FIGURES 11 and 12, in FIGURES 9 and 10 for illustrative purposes relative freedom from physical contact has been shown to avoid obscuring the operative relationships of the elements and parts.

By employing the principles of the method and apparatus according to the present invention numerous and varied bias weaving patterns and effects can be attained. For example, referring to FIGURE 13, three filament patterns can be achieved simultaneously. These comprise a basic braided helix **87** of which the weaving elements cross over to and provide the opposite surfaces of the woven article, with inner longitudinal elements **88** and inner helical elements **89** within the wall of the article as layers or integrated with one another, and all woven together by the elements **87**. By having all three of the patterns **87, 88** and **89** interwoven, all separating boundary layers are avoided, and a thoroughly reinforced covering or hollow structural shape is afforded. As illustrated, this combination of three weaving patterns is applied to a conic frustrum configuration.

Hollow shape braiding may be effected as schematically illustrated in FIGURE 14. One or more of the rotary drum guide nests **60'** is operatively mounted concentrically about a non-rotary mandrel **90** mounted on a longitudinally reciprocal supporting guide rod or post **91** and the mandrel is fed at a controlled weaving rate correlated to the speed of weaving movement of elements **92** emanating from the weaving face of the guide nest **60'**. To attain the three pattern arrangement of FIGURE 13, separate coaxially related guide nests are provided with the helical patterns created by respective rotating guide drum nests and the straight pattern created by a stationary guide nest. All of the guide nest drums may be coaxially assembled in operative relation, or in separate axially spaced relation, as preferred.

If desired, an overwrap filament **93** may be wound about the conical woven article on the mandrel **90** by means of a rotating overwrap head **94** suitably motivated in a circular path about the mandrel in clearance relation to a mandrel feeding device **95** operatively connected to the opposite end of the mandrel from the reciprocal base rod guide support **91**. A large variety of hollow shapes is adapted to be produced by appropriate configuration of the mandrel **90** ,for externally pressurized shells, re-entry heat shields, rocket motor chambers and nozzles, high temperature furnace and ladle linings, permanent or semi-permanent steel or gray iron casting molds, etc.

Various structural shapes are adapted to be woven according to the principles of the present invention, utilizing longitudinal forms which are drawn through the weaving head or nest in a manner to receive the bias woven material thereabout continuously as the form advances at a rate synchronized with the weaving speed. After completion, the woven shapes may be rolled or folded for packaging because of the flexibility of the weaving elements. Final rigid form, where desired, is achieved by stretching the hollow shapes and applying matrix binder and curing the same.

One example of structural shape weaving is depicted in FIGURE 15 wherein a generally I-beam elongated form **97** is mounted to travel operatively through a weaving head **98** within which one or more guide nests are operatively mounted about the form **97** to effect weaving orientation of weaving elements **99** pressed by take off pressure rollers **100** and **101** against the contours of the shaping form **97**, from which completed article **102** is then suitably stripped.

In FIGURE 16 is depicted an example of double wall or skin and connecting web woven shape as an example of one of the numerous and varied shapes and configurations that may be produced according to the present invention. In this example, opposite longitudinal walls **103** and **104**, spaced apart as little or much as desired, are connected by longitudinal webs **105**, all integrally bias woven as a unit. While the web-divided sections may comprise part of a large hollow shape, they may be part of a panel of flat or any other desired configuration. As shown, the sections may be angularly related in part of the panel and in semi-cylindrical curved relation in another part of the panel, or they may all be woven into the angularly related shape first and thereafter brought to a finished semi-cylindrical or other desired shape, as is permitted by yielding and stretching of the fabric.

FIGURE 17 depicts a flat panel double skin panel **107** having branched connecting webs **108**, in this instance providing generally cylindrical longitudinal tubular passages through the hollow panel. It will be obvious, however, that the connecting webs may take on various forms and relative orientations to one another and to the outer boundary layers or skins or walls of the panel or shape **107**.

From the foregoing, it will be apparent that according to the principles of the present invention a great variety of bias woven and braided articles is adapted to be produced from various types and grades and mixtures of yarns, threads, filaments, and the like, all generically referred to herein as weaving elements. Great versatility is afforded as to the type, configuration, weight, thickness, density, looseness, etc., in the articles produced. For high performance thermal or structural articles incorporating filaments, threads, yarns, and the like, impregnated with a binder either before or after weaving and the binder then cured by appropriate processes to achieve the desired end article characteristics, the present invention is especially desirable. Because of the simple, positive, free slippage guiding of the weaving elements pursuant to the invention operational weaving speeds far in excess of conventional loom weaving rates are attainable, such as on the order of twenty to one hundred times as fast. Bias weaving angles are infinitely variable from nearly perpendicular to near parallel to the direction of weaving. In broadgoods 45° bias angle weaving will afford a fabric with perpendicular cross weaving when cut at 45° to the direction of weaving. Bias woven structural lay-up fabrics are ideal for shape conformity. These fabrics will stretch in all directions. Directional strength properties can be achieved by stretching in the direction of desired strength. The directional strength is proportional to the weave alignment in the direction of stretch. Other desirable features and advantages will also be readily apparent from the disclosure.

In the following claims the term "bias weaving" includes braiding.

It will be understood that variations and modifications may be effected without department from the spirit and scope of the novel concepts of this invention.

I claim as my invention:

1. A method of bias weaving comprising:

continuously moving a plurality of individual weaving elements into one end of and through respective guide eyes of individual guide members and then from the opposite ends of the eyes and therebeyond interengaging the elements into a woven article;

moving the article away from the guide members; and relatively cooperatively moving said guide members in a predetermined bias weaving pattern within a weaving plane generally normal to the weaving direction and comprising directing the guide members to follow generally zig-zag respective crossing paths and thereby orienting said elements in over and under crossing interwoven relation while the elements are in movement as aforesaid.

2. A method according to claim **1**, comprising guiding the interwoven elements into skin layers and connecting webs in the woven article.

3. A method according to claim **1**, comprising guiding each of the interwoven elements progressively into opposite boundary and intermediate layers in the woven article.

4. A method according to claim **1**, comprising periodically angularly changing the direction of travel of the members in said paths.

5. A method according to claim **4**, comprising effecting a timing dwell of the members respectively as their direction of travel is changed.

6. A method according to claim **1**, comprising pressing the article onto a shaping form traveling relative to the guide members at a speed synchronized with the weaving speed.

7. A method as defined in claim **1**, including guiding respective ones of the weaving elements into three weaving patterns simultaneously comprising a basic braided helix pattern, a basic helix pattern, and longitudinally oriented pattern of elements, with the basic helix and longitudinal element pattern woven within the wall of the article while the basic braided helix elements are guided from surface to surface of the article.

8. Apparatus for bias weaving comprising:

individual guide members having guide eyes therethrough through which individual weaving elements are freely slidably threaded;

means supporting said guide members in a nest in a weaving plane extending across a weaving direction axis;

means operative to move said guide members in predetermined relative generally zig-zag crossing respective weaving paths in said plane to guide said weaving elements progressively into over and under crossing interwoven relation; and

means operative to take off the interwoven elements as a woven article from a weaving face of said nest at a speed synchronized with weaving movement of said members in said nest.

9. Apparatus according to claim **8**, having means for delivering the weaving elements to a back face of the weaving nest in a direction substantially normal to the weaving direction whereby the elements freely pass one another and avoid any cross-over relation to one another where they enter the guide members.

10. Apparatus according to claim **8**, having means for delivering the weaving elements to the back face of the guide nest substantially in the direction of weaving and including tension means spaced substantially from said back face, takeoff rollers engaging the woven article close to the weaving face of said guide nest, and said guide member moving means being operative to drive the guide members in their weaving paths and also periodically alternately in an unweaving reverse direction.

11. Apparatus according to claim **8**, comprising, in addition, a shaping form travelling relative to the guide members at a speed synchronized with the weaving speed, and means for pressing the woven article onto the shaping form.

12. Apparatus according to claim **8**, in which said means operative to move said guide members operates to change the direction of travel of the members angularly at periodic intervals in said paths.

13. Apparatus according to claim **12**, in which said supporting means comprise means acting at said changes of travel direction to effect timing dwell of the members.

14. Apparatus according to claim **13**, in which said supporting means provide a frame around said nest, said guide members comprise internested blocks disposed in planar alignment in rows extending in two directions and respective plungers operating in timed relation to shift the rows of blocks in both of said directions.

15. Apparatus according to claim **8**, in which said guide members comprise respective tubes, said means operative to move said guide members comprising rotary transfer devices disposed in cooperative rows in two directions in said weaving plane with perimeters of the adjacent devices in mutual proximity to one another, said perimeters having indentations in which said members are carried, said indentations being coordinated to align cyclically for transfer of the guide members from one transfer device to the other, means for effecting transfer of the guide members from transfer device to transfer device, and spacer means between each four of the transfer devices.

16. Apparatus according to claim **15**, in which said supporting means comprise a frame in which said rotary transfer devices are supported, said frame having timing dwell notches in which said guide members are received incident to changes of direction in their respective paths of movement.

17. Apparatus for bias weaving comprising:

individual guide members having guide eyes therethrough through which individual weaving elements are freely slidably threaded;

means supporting said guide members in a nest and including means operative to move said members in predetermined relative weaving paths defining a weaving pattern in a weaving plane extending across a weaving direction axis; and

means operative to take off the interwoven elements as a woven article from a weaving face of said nest at a speed synchronized with weaving movement of said members in said nest;

said guide members comprising internested blocks having the eyes in the form of bores extending from a back face of the blocks to said weaving face.

18. Apparatus for bias weaving comprising:

individual guide members having guide eyes therethrough through which individual weaving elements are freely slidably threaded;

means supporting said guide members in a nest and including means operative to move said members in predetermined relative weaving paths defining a weaving pattern in a weaving plane extending across a weaving direction axis; and

means operative to take off the interwoven elements as a woven article from a weaving face of said nest at a speed synchronized with weaving movement of said members in said nest;

said guide members comprising tubes with the bores of the tubes comprising the eyes through the members;

said means for moving the members including reciprocating transfer blocks providing transfer pockets in which said tubes are operatively supported.

19. Apparatus for bias weaving comprising:

individual guide members having guide eyes therethrough through which individual weaving elements are freely slidably threaded;

means supporting said guide members in a nest and including means operative to move said members in predetermined relative weaving paths defining a weaving pattern in a weaving plane extending across a weaving direction axis; and

means operative to take off the interwoven elements as a woven article from a weaving face of said nest at a speed synchronized with weaving movement of said members in said nest;

said guide members comprising tubes with the bores of the tubes comprising the eyes through the members;

said means for moving the guide tube members comprising rotary transfer devices comprising:

drum assemblies each of which includes a pair of spaced oppositely facing peripherally indented transfer disks,

driving gear means and spring cam tube biasing means between said disks,

floating spacers slidably engaging the disks, and

guide nest supporting frame structure operatively supporting the transfer drum assemblies on individual rotary axes without obstructing the back and weaving faces of the guide nest.

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