

June 26, 1962

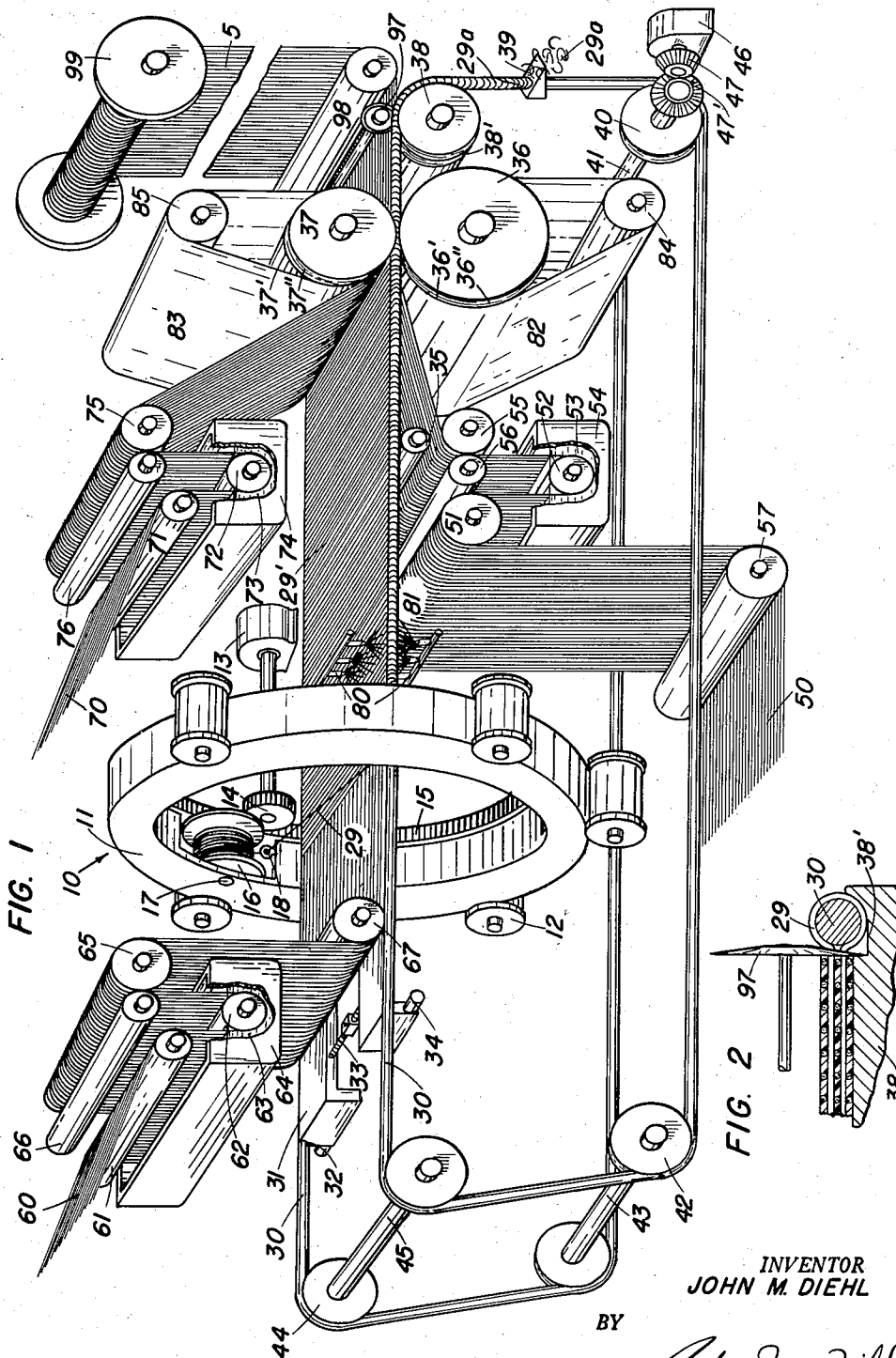
J. M. DIEHL

3,041,230

NON-WOVEN FABRIC MACHINE AND METHOD

Filed Nov. 21, 1958

12 Sheets-Sheet 1



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NON-WOVEN FABRIC MACHINE AND METHOD

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12 Sheets-Sheet 2

FIG. 3

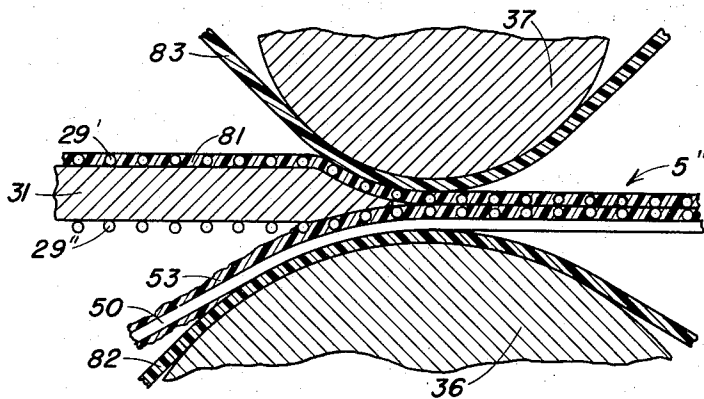


FIG. 4

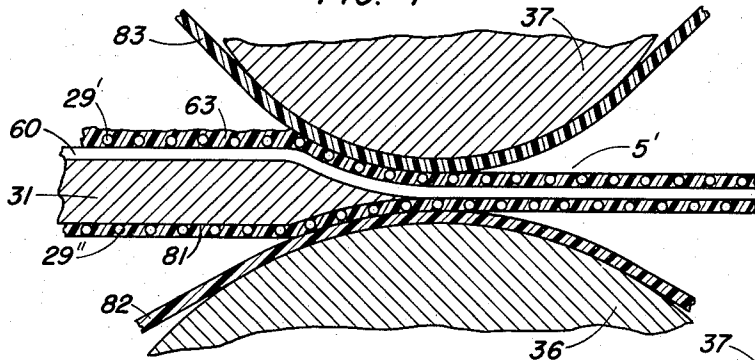


FIG. 5

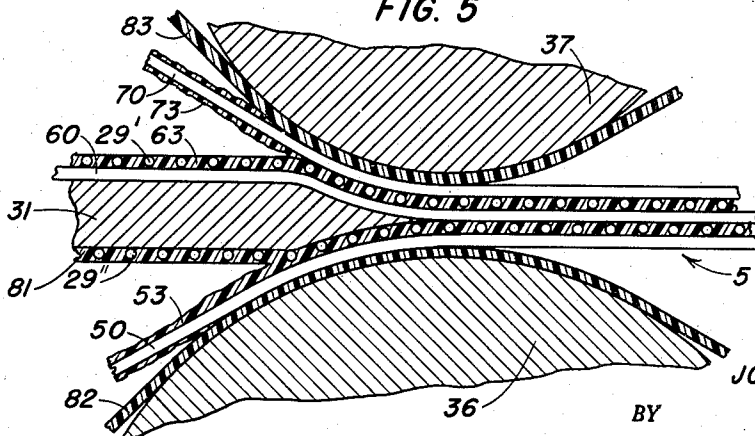
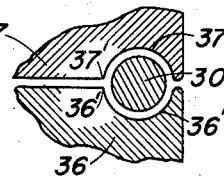


FIG. 6



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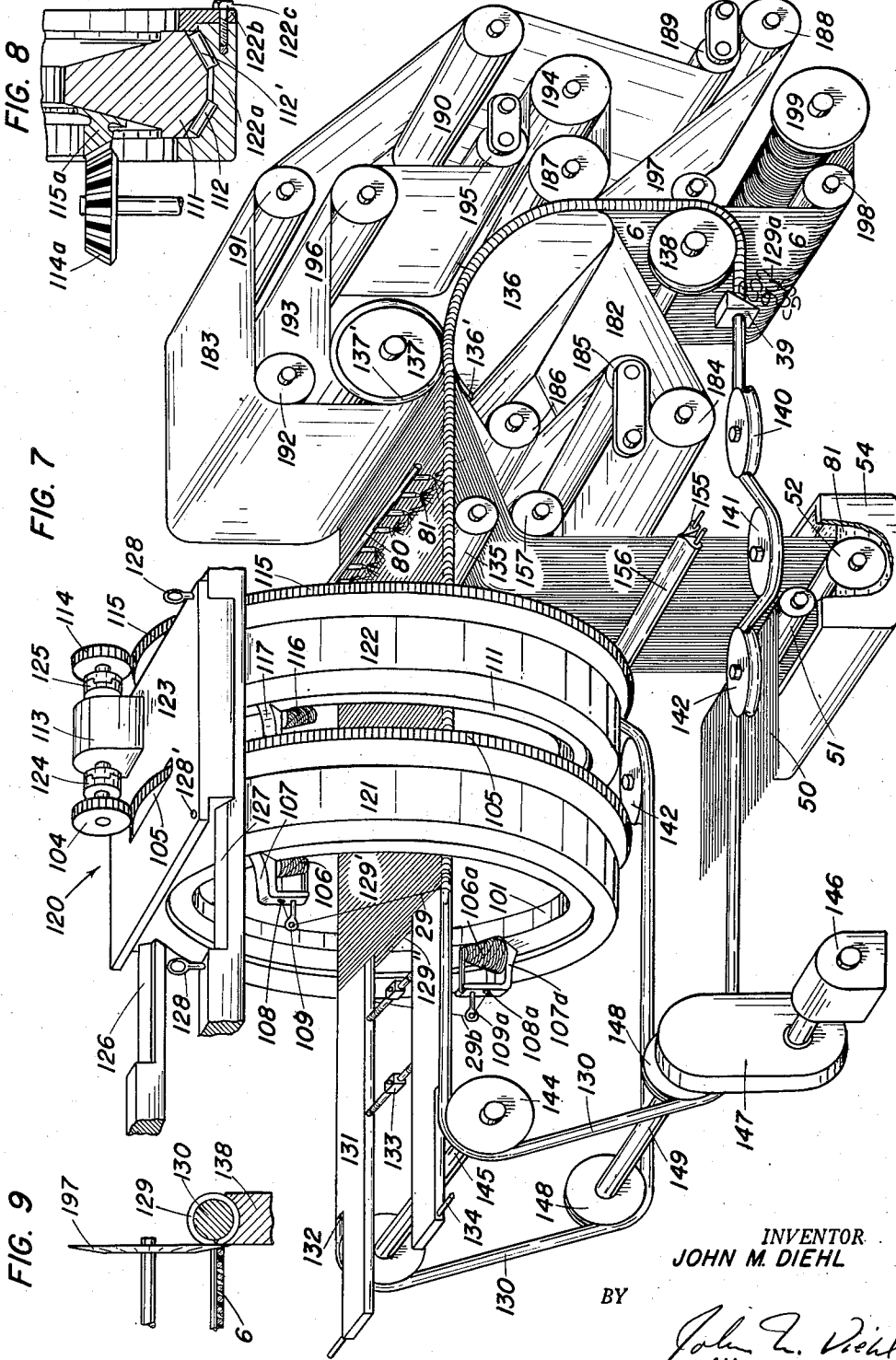
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NON-WOVEN FABRIC MACHINE AND METHOD

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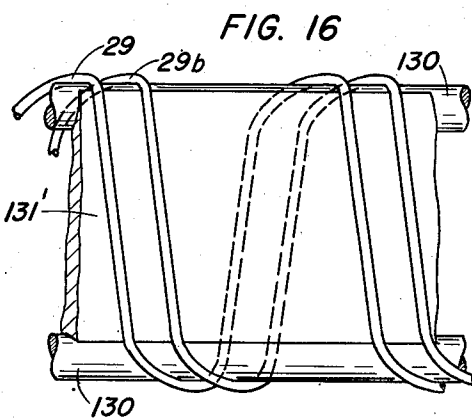
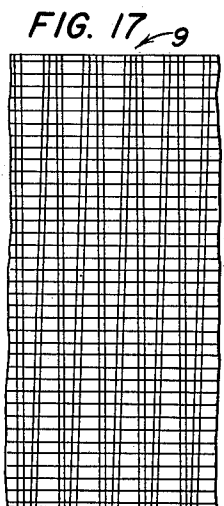
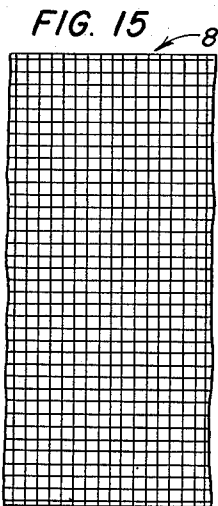
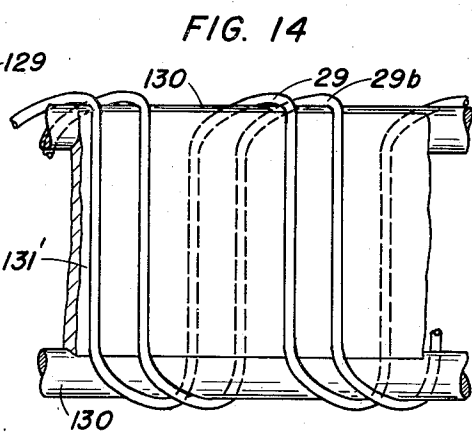
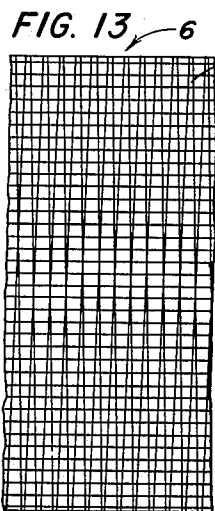
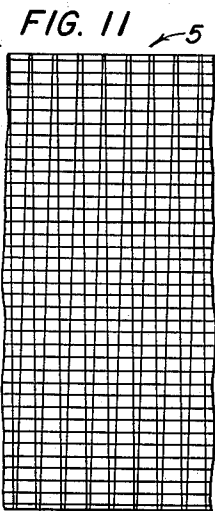
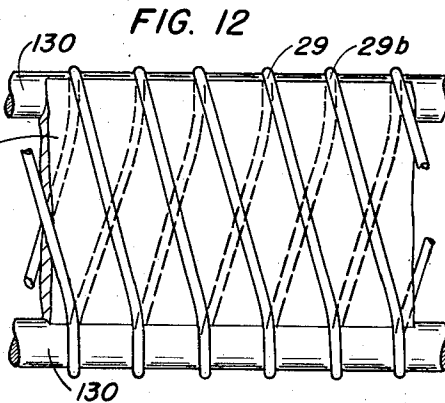
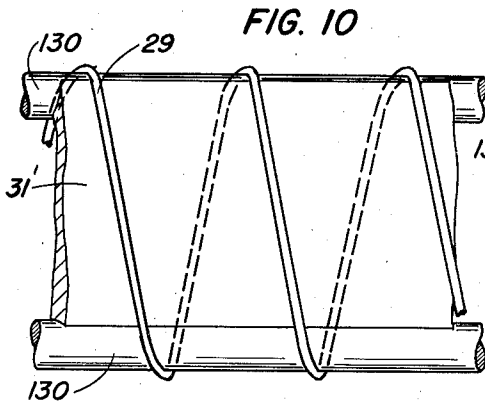
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NON-WOVEN FABRIC MACHINE AND METHOD

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12 Sheets-Sheet 4



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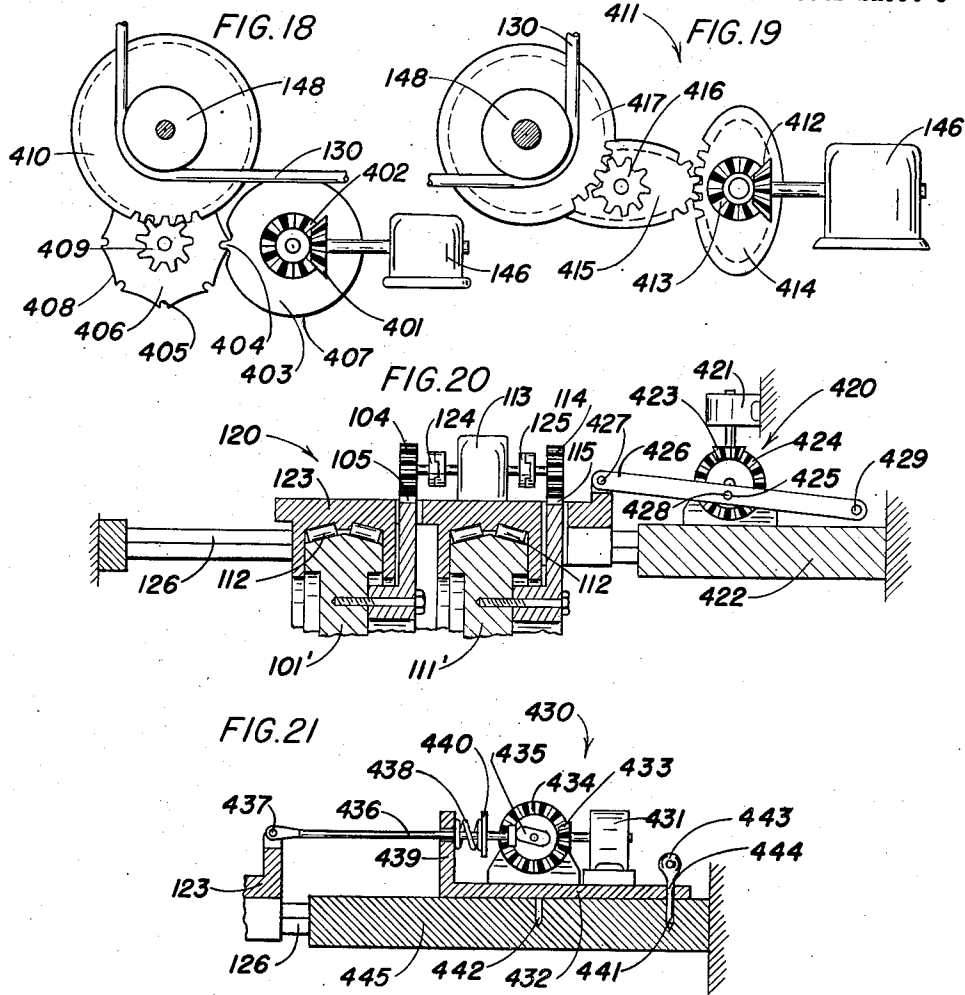
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NON-WOVEN FABRIC MACHINE AND METHOD

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12 Sheets-Sheet 5



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NON-WOVEN FABRIC MACHINE AND METHOD

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FIG. 22

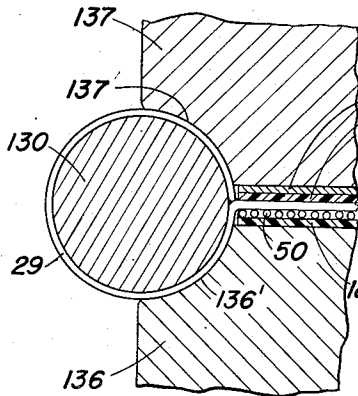


FIG. 23

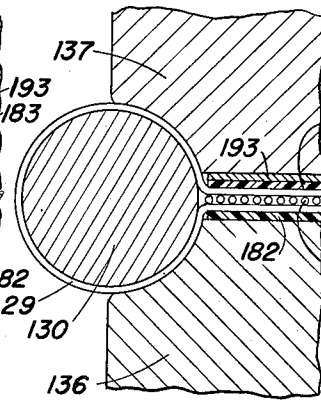


FIG. 24

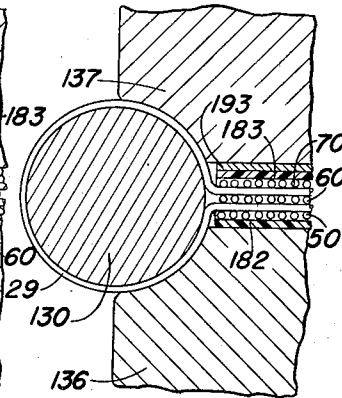


FIG. 25

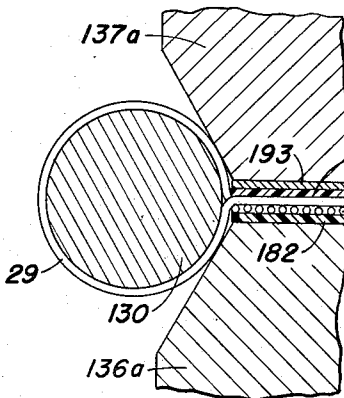


FIG. 26

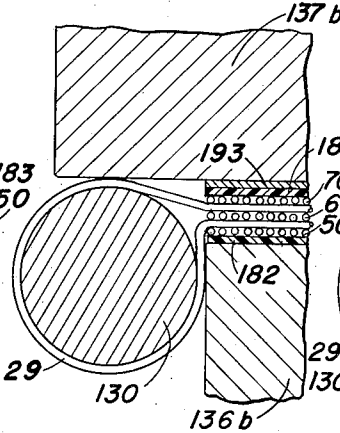


FIG. 27

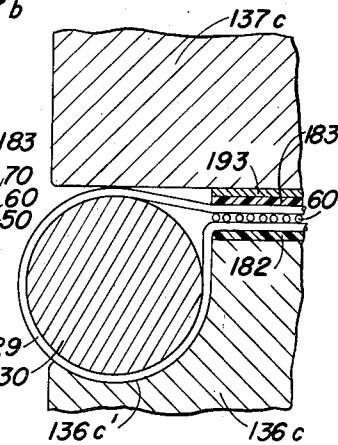


FIG. 28

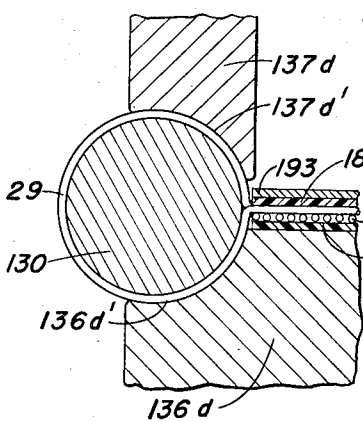


FIG. 29

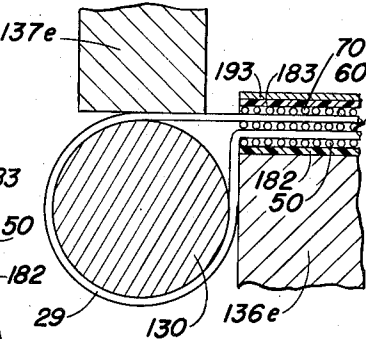
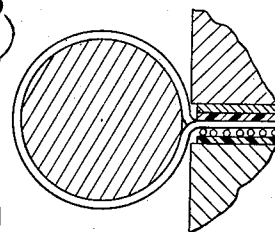


FIG. 30



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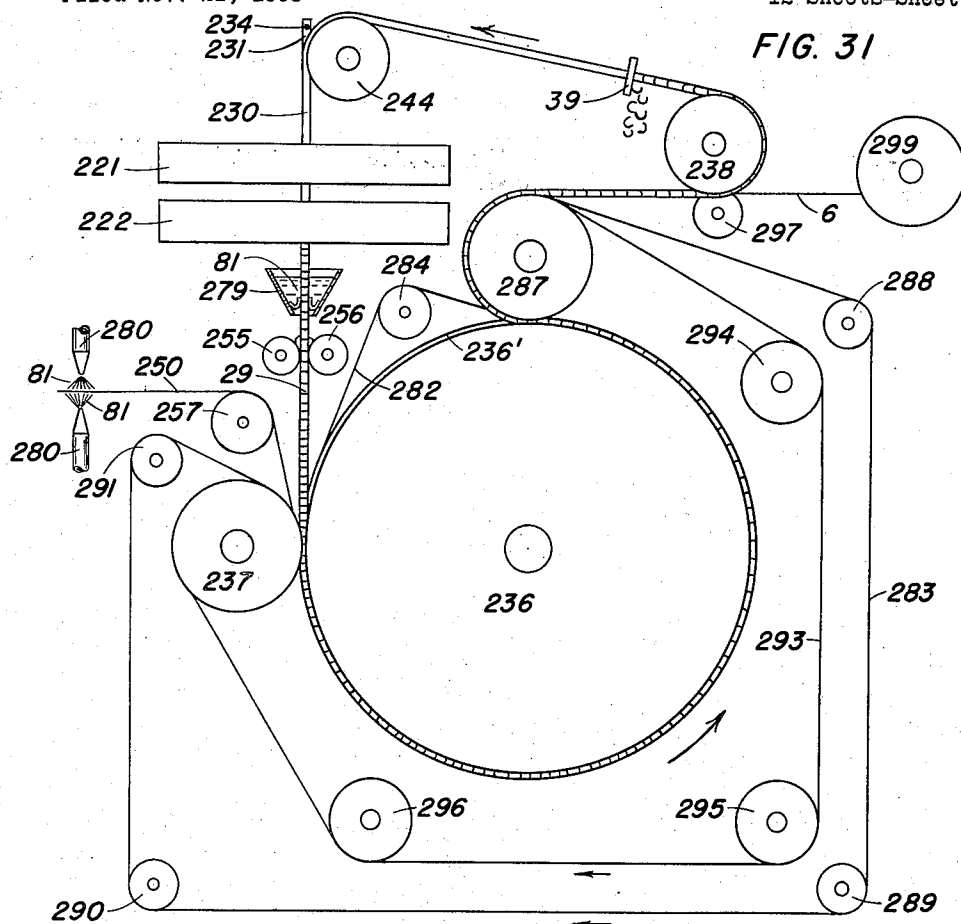
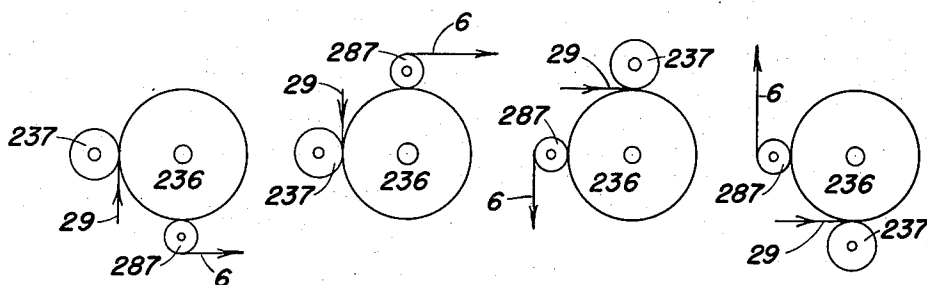


FIG. 32

FIG. 33

FIG. 34

FIG. 35



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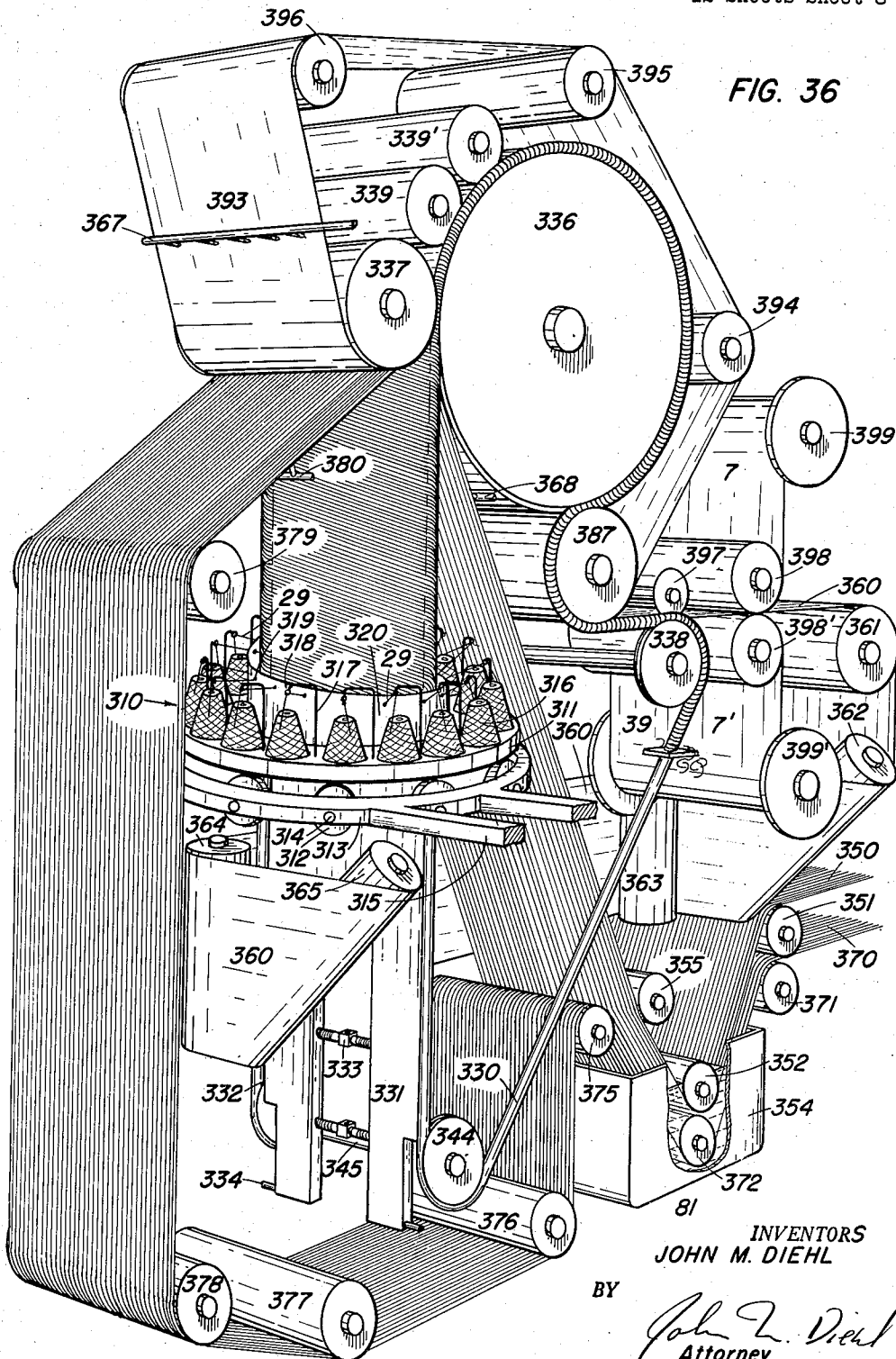
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NON-WOVEN FABRIC MACHINE AND METHOD

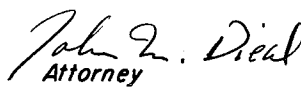
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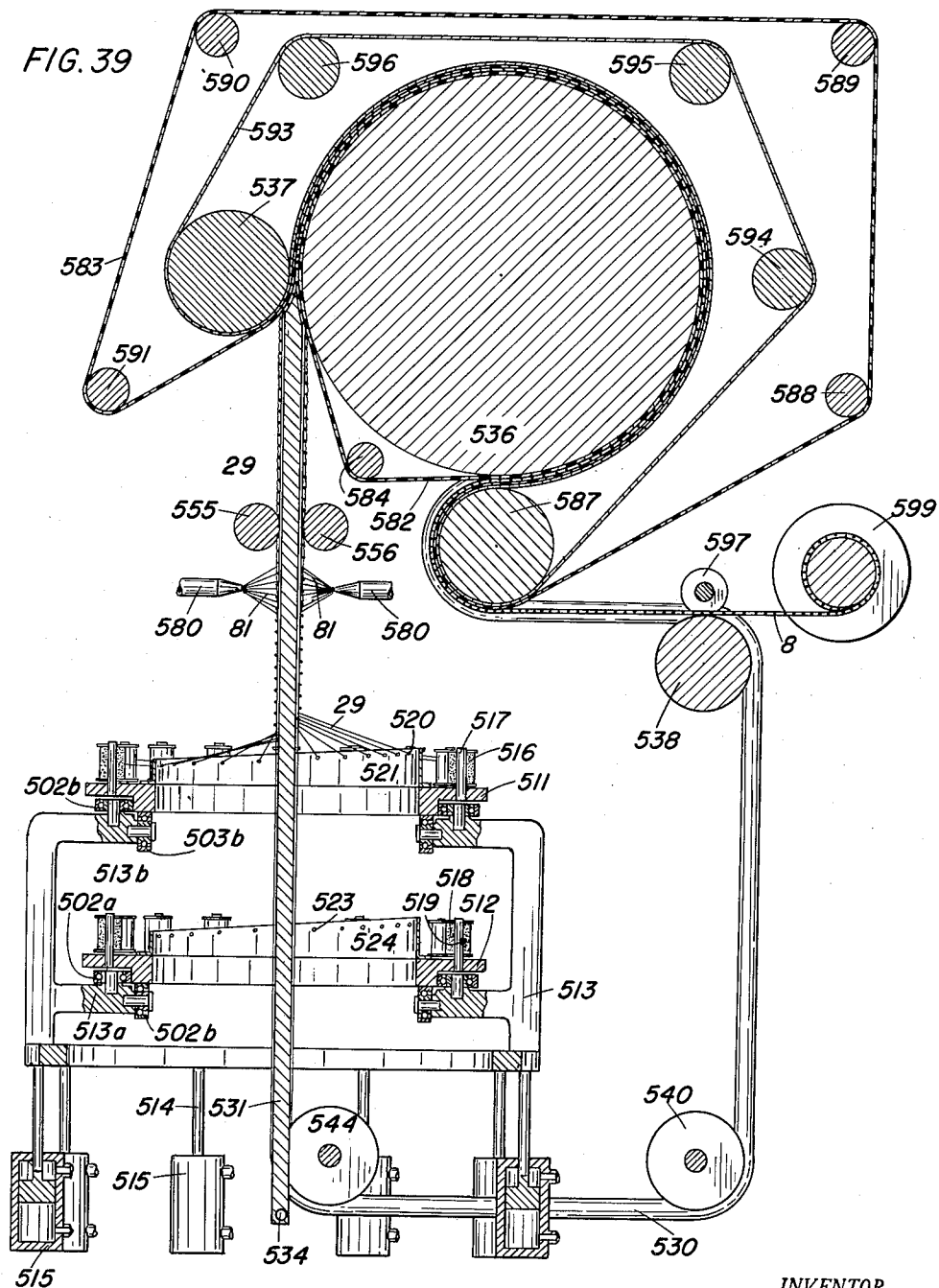
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NON-WOVEN FABRIC MACHINE AND METHOD

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12 Sheets-Sheet 10



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NON-WOVEN FABRIC MACHINE AND METHOD

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FIG. 40

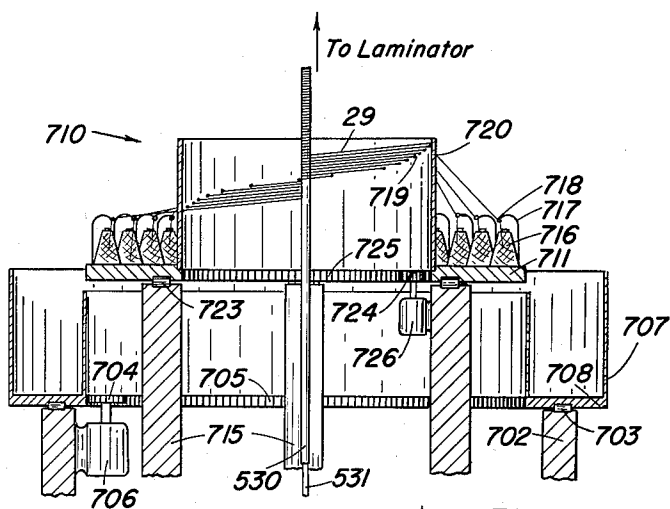


FIG. 41

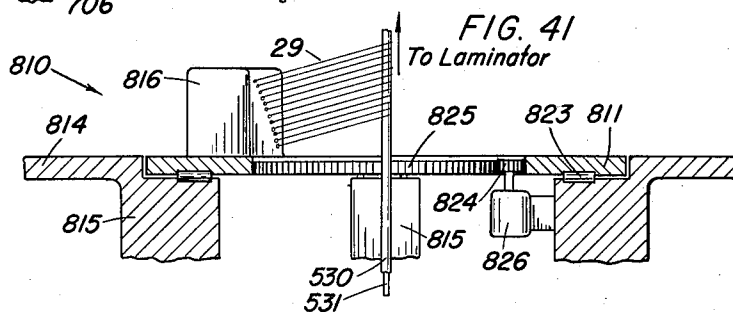
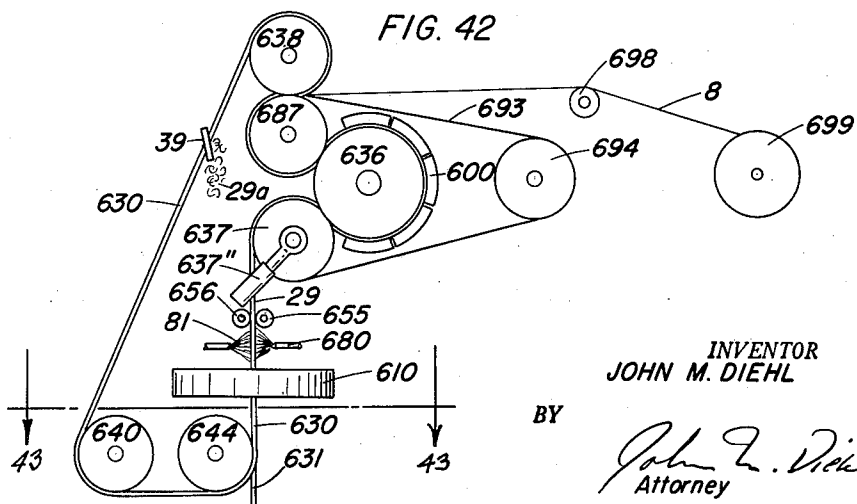


FIG. 42



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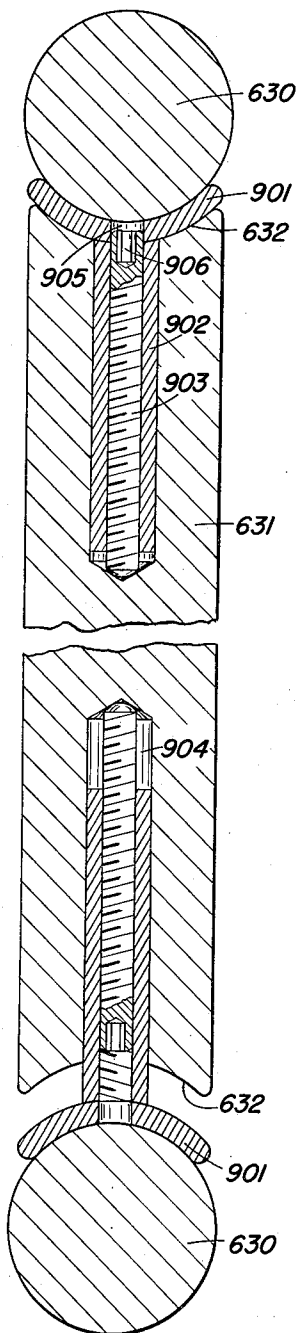
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NON-WOVEN FABRIC MACHINE AND METHOD

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FIG. 43



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NON-WOVEN FABRIC MACHINE AND METHOD
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Wichita, Kans.

Filed Nov. 21, 1958, Ser. No. 777,538
27 Claims. (Cl. 156—172)

This invention relates to a device and method for producing a sheet of non-woven fabric comprising substantially parallel strands of yarn secured together with a polymeric material.

The copending applications Serial No. 334,592 of Diehl and Bjorksten, filed February 2, 1953, now abandoned, and Serial No. 361,992 of Diehl and Rennat, filed June 16, 1953, now abandoned, show a machine and method for making non-woven fabrics. The usual methods for producing a multiple layer non-woven fabric with parallel crossing layers of parallel strands of yarn secured together with synthetic resin were essentially batch-wise in nature. Even those methods which could be carried out continuously utilized automatic repetition of steps of an essentially batch-wise process. By an entirely different process, we have made it possible to produce such material in smoothly continuous production. Such material is disclosed in co-pending application Serial No. 317,072, filed October 27, 1952, now abandoned, by Luther L. Yaeger, entitled Dimensionally Stable Cartographic Base, and in co-pending application Serial No. 339,152, filed February 26, 1953, now abandoned, entitled Non-Woven Fabric.

The subject matter of this patent may be used by or for the Government for governmental purposes without the payment of any royalties to me.

The term "fabric" is used herein in the sense of definition 5b in Webster's New International Dictionary of the English Language, Second Edition, Unabridged, G. & C. Merriam Company, Springfield, Mass., 1949, page 906, definition 5. "Any thing manufactured; in modern use: a Cloth that is woven or knit from fibers, either vegetable or animal; as, silk, or other fabrics. b Any similar material."

The term "yarn" is used herein in the sense that "yarn" is defined in A.S.T.M. (American Society of Testing Materials), Definitions of Textile Terms (D123-49): "A generic term for an assemblage of fibers or filaments, either natural or manufactured, twisted or laid together, to form a continuous strand suitable for use in weaving, knitting, or otherwise intertwining to form textile fabrics. NOTE.—Varieties include single yarn, ply yarn, cord, twine, sewing thread, etc." and more particularly in the sense that the term is defined in a recent proposed revision of the present definition appearing in Tentative Definitions of Terms Relating to Textile Materials, 1951 supplement to Book of A.S.T.M. Standards Including Tentatives, page 37, under Tentative Definitions of Terms Relating to Textile Materials (D123-51T): "A generic term for continuous strands of textile fibers or filaments in a form suitable for knitting, weaving, or otherwise intertwining to form a textile fabric. It may comprise:

- (a) A number of fibers twisted together,
- (b) A number of filaments laid together without twist (a zero-twist yarn),
- (c) A number of filaments laid together with more or less twist, or
- (d) A single filament with or without twist (a monofilament).

"NOTE.—Varieties include single yarn, ply yarn, cord, twine, sewing thread etc."

An object of this invention is therefore to provide a suitable device and method for producing a sheet of non-woven fabric comprising a plurality of substantially parallel layers of parallel strands of yarn secured together with

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a polymeric material with the strands of one layer crossing those of the adjacent layer.

Another object is a device and method for producing a sheet of material comprising polymeric resin having embedded therein at least two planar layers of strands of yarn wherein said strands in each of said layers are at least substantially parallel to one another and have their axes in the same plane and extend substantially from one edge of said sheet to the opposite edge of said sheet, said planes being at least substantially parallel to one another.

Another object is such a device and method wherein two layers of strands are formed by winding one or more strands around parallel spaced portions of a pair of endless movable flexible members such as cables.

Another object is a device and method for maintaining strands in two or more substantially parallel layers of substantially parallel strands of yarn in a desired orientation and under tension while polymerizable material is applied thereto and while said material is polymerized.

Further objects will become apparent from the drawings and from the following detailed description in which it is my intention to illustrate the applicability of the invention without thereby limiting its scope to less than that of all those equivalents which will be apparent to those acquainted with the art and in which like reference numerals refer to like parts and in which;

FIGURE 1 is a partially cut-away schematic perspective view from one side of one embodiment of the invention;

FIGURE 2 is a transverse cross-sectional view of a portion of the device shown in FIGURE 1;

FIGURE 3 is a longitudinal cross-sectional view at the bite of the laminating rolls shown in FIGURE 1 showing one warp and two layers of crosswise strands passing through said bite;

FIGURE 4 is a longitudinal cross-sectional view at the bite of the laminating rolls shown in FIGURE 1 showing two layers of crosswise strands and a warp interposed therein between passing through said bite;

FIGURE 5 is a longitudinal cross-sectional view at the bite of the laminating rolls shown in FIGURE 1 with materials passing therethrough corresponding to those shown in FIGURE 1;

FIGURE 6 is a transverse cross-sectional view at one end of the bite of the laminating elements illustrated in FIGURE 1;

FIGURE 7 is a partially cut-away schematic perspective view from one side of another embodiment of the device of the invention;

FIGURE 8 is a cross-sectional view of a modification of one of the winder rings shown in FIGURE 7;

FIGURE 9 is a transverse cross-sectional view of a portion of the device shown in FIGURE 7;

FIGURE 10 is a perspective view of a pair of parallel movable flexible members with interposed means adapted to maintain parallel relationship of said members, with a single end or strand wound therearound, the view being taken from a point perpendicular to said movable members and slightly removed from the plane of said interposed means;

FIGURE 11 is a plan view of material which may be made according to the invention, utilizing the arrangement illustrated in FIGURE 10;

FIGURE 12 is a perspective view of endless moveable flexible members and interposed means corresponding to FIGURE 10 with two strands wound therearound;

FIGURE 13 is a plan view of material which may be made according to the invention, utilizing the arrangement shown in FIGURE 12;

FIGURE 14 is a perspective view of the elements shown in FIGURE 12, the strands being wound so as to make them parallel between said endless moveable flexible members;

FIGURE 15 is a plan view of material which may be made according to the invention, utilizing the arrangement of FIGURE 14;

FIGURE 16 is a perspective view of the elements illustrated in FIGURE 14 with two strands being wound around said endless moveable flexible members and said interposed means in such a manner as to provide strands on one side of said interposed means which are not altogether parallel to those on the other side of said interposed means;

FIGURE 17 is a plan view of material which may be made according to the invention, utilizing the arrangement of FIGURE 16;

FIGURE 18 is an elevation of modified driving means which may be applied to the endless moveable flexible members of the device illustrated in FIGURE 7;

FIGURE 19 is an elevation of another form of driving means which may be applied to the endless moveable flexible members of the device illustrated in FIGURE 7;

FIGURE 20 is a partially cross-sectional schematic elevation of means which may be applied to the winder assembly of the device illustrated in FIGURE 7 as a modification of the device to provide oscillatory motion of the winder;

FIGURE 21 is a partially cross-sectional schematic elevation of another embodiment of means for oscillating the winder assembly of the device illustrated in FIGURE 7;

FIGURE 22 is a transverse cross-sectional view at one end of the bite of the laminating elements of FIGURE 7;

FIGURE 23 is a transverse cross-sectional view at one end of the bite of the laminating elements of FIGURE 7 showing a warp disposed between two crosswise layers of strands;

FIGURE 24 is a transverse cross-sectional view at one end of the bite of the laminating elements of FIGURE 7 with three warps and two interposed layers of crosswise strands passing therethrough;

FIGURE 25 is a transverse cross-sectional view at one end of the bite of a modification of the laminating elements of FIGURE 7;

FIGURE 26 is a transverse cross-sectional view at one end of the bite of another embodiment of the laminating elements of FIGURE 7;

FIGURE 27 is a transverse cross-sectional view at one end of the bite of laminating elements which may be modifications of those shown in FIGURE 7;

FIGURE 28 is a transverse cross-sectional view at the edge of a laminating element with a sheave adjacent thereto;

FIGURE 29 is another transverse cross-sectional view at the edge of a laminating element with another form of sheave adjacent thereto;

FIGURE 30 is a transverse cross-sectional view at one end of the bite of laminating elements which may be modifications of those illustrated in FIGURE 7;

FIGURE 31 is a schematic elevation of another embodiment of the device of the invention;

FIGURE 32 is a schematic elevation of some of the principal elements of the device of the invention illustrating one physical arrangement thereof;

FIGURE 33 is a schematic elevation of some of the principal elements of the device of the invention illustrating another arrangement thereof;

FIGURE 34 is a schematic elevation of some of the principal elements of the device of the invention illustrating another arrangement thereof;

FIGURE 35 is a schematic elevation of some of the principal elements of the device of the invention illustrating another arrangement thereof;

FIGURE 36 is a partially cut-away perspective schematic view of another embodiment of the device of the invention;

FIGURE 37 is a schematic perspective view from

one side of another embodiment of the device of the invention;

FIGURE 38 is a plan view of strands wound around the endless moveable flexible members of the device shown in FIGURE 37;

FIGURE 39 is a schematic cross-sectional view of another embodiment of the invention differing only slightly from the embodiment illustrated in FIGURE 37;

FIGURE 40 is a schematic cross-sectional view of a device for winding strands around endless moveable flexible members and means interposed therebetween to hold said members parallel;

FIGURE 41 is a schematic cross-sectional view of another device for winding strands around endless moveable flexible members and means interposed therebetween to hold said members parallel;

FIGURE 42 is a schematic elevation of another embodiment of the device of the invention;

FIGURE 43 is an enlarged cross-sectional view of a table, which may hold endless flexible members in parallel relationship, taken on lines 43—43 in FIGURE 42.

The invention broadly consists of building two layers of strands around a pair of moveable flexible members such as cables held spaced apart in parallel relationship, the said layers being built therearound by means of one or more winding devices. Such parallel members are adapted to be moveable longitudinally with respect to their own length and to carry the layers of strands into conjunction with laminating elements. Polymerizable synthetic resin may be applied to one or more of the layers of strands and the layers of strands with resin thus applied, may then be run through laminating elements which may be rolls, or a roll and an endless metal sheet and possibly one or more shoes or a roll and a shoe or shoes adapted to cure (polymerize) the resin under heat and pressure. The moveable flexible members are held apart by means interposed therebetween at all stages of the process and therefore maintain tension in the strands and maintain the orientation thereof. Such interposed means may consist of the laminating elements themselves.

In FIGURE 1 there is shown schematically one embodiment of the device of the invention. Winder 10 may consist of a ring 11 turning on rollers 12 which may be rotatably supported in place by means not shown. Ring 11 may be caused to revolve by motor 13 driving spur gear 14 which may act upon internal gear teeth 15. Spool or cop 16 may be rotatably mounted on shaft 17 attached to ring 11. A strand of yarn 29 unwinding off spool 16 may first pass through one or more suitable eyelets such as 18 and may then pass repeatedly around a pair of substantially parallel portions of endless moveable flexible members which may be cables 30. Cables 30 may pass through ring 11 and may be held in the desired parallel relationship by interposed means such as table 31 provided with concave grooves 32 at its edges in which cables 30 may slide. To facilitate sliding of cables 30 in grooves 32, the grooves may be lubricated with any viscous oily material compatible with the synthetic resin or resins subsequently utilized to attach crossing layers of strands together or even with a non-compatible lubricant which may be a suitable mineral oil or the like. For example, if the resin is a polyester, the lubricant may be glycol. Cables 30 may be of any suitable material such as steel or stainless steel and may, if desired, be jacketed with a yieldable material such as natural or synthetic rubber or a synthetic resin such as for example, a polyester, a polyamide, a polytrifluoro-chloroethylene, a silicone or a tetrafluoroethylene, to provide a smooth surface and thus to lessen the possibility of breaking the fill strands therearound.

Table 31 may be provided with means such as turn-buckle-like adjusting bolts 33, to adjust its width and to thus provide a slightly greater width at one end or the other as may be found necessary in operation or to

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vary the average width as may be found necessary under varying circumstances to provide the proper tension on strands 29 wrapped therearound. Table 31 may be hingeably mounted near the end with which cables 30 first became engaged, by means of shafts 34 which may rotate in journals which are not shown. The other end of table 31 may be supported by rotatable means such as roll 35. Sheaves or a plurality of rolls of smaller face width than roll 35 may suitably be used in place of roll 35.

Cables 30 may travel endlessly clockwise passing in turn alongside table 31, thence alongside the bite of laminating rolls 36 and 37, thence over grooves 38' in roll 38, thence through strippers 39 and thence in turn over sheaves 40 on shaft 41, sheaves 42 on shaft 43 and sheaves 44 on shaft 45 and thence again alongside table 31. If desired, roll 38 may be supplanted with sheaves such as 40 and 42. Sheaves 42 and 44, which are idlers, need not necessarily be mounted on common shafts. Cables 30 may be caused to travel in the manner described by means of motor 46 or other constant driving means driving a pair of sheaves 40 (one of which is not shown) either directly or through any suitable constant speed gear reduction such as bevel gears 47 and 47'. As shown bevel gear 47 is securely attached to shaft 41, to which are securely attached sheaves 40 and thus each of sheaves 40 is caused to rotate at the same rate of speed. If desired, sheaves 40 may be mounted on separate shafts, or otherwise independently, and may be driven by suitable power transmission means adapted to cause said sheaves to rotate at the same rate and thereby adapted to cause cables 30 to travel at the same rate of speed.

As winder ring 11 rotates, strand 29 is wound around table 31 and juxtaposed cables 30 so as to form two layers of strands, one layer being above table 31 and the other being below table 31. As cables 30 move in the manner described above, they may carry with them these layers of strands into the bite of laminating rolls 36 and 37. The fill strands in the layer above the table are designated 29' and those in the layer below the table are designated 29'' (not shown).

Warps 50, 60, and 70 may be built on continuous warping machines of the type well known to the art. They may pass over suitable direction changing idler rolls, such as 51, 61 and 71, thence over idler rolls such as 52, 62 and 72, immersed in liquid polymerizable material such as 53, 63 and 73 contained in baths 54, 64 and 74 and they may thence pass between pairs of squeeze rolls such as rolls 55 and 56, rolls 65 and 66 and rolls 75 and 76 adapted to remove excess polymerizable material from the warp beams. Rolls 55, 65 and 75 may suitably be adapted to cause the warp beams to again change direction as shown. Warp beam 50 may pass into conjunction with strands 29' substantially at the bite of rolls 36 and 37; warp beam 60 may pass over roll 67 and thence travel adjacent the top of table 31 under layer of strands 29'; and warp beam 70 may pass from roll 75 into the bite of laminating elements 36 and 37 at which place it may come into conjunction from above with strands 29'. Pairs of wiper blades may be used in place of pairs of rolls 55 and 56, 65 and 66, and 75 and 76 or rolls 56, 66 and 76 may be replaced with wiper blades operating in conjunction with rolls 55, 65 and 75 to remove excess polymerizable material from the warp beams.

Polymerizable materials 53, 63 and 73 may be any material which may be polymerized to form a synthetic resin; for most purposes it is preferable that a resin formed by polymerizing this material be flexible and for some applications it is desirable that it be transparent. Polyester resins have been found especially suitable for many applications.

Polymerizable materials 53, 63 and 73 are carried into the bite of rolls 36 and 37 by the warp beams 50, 60 and

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70 as shown in greater detail in FIGURES 3, 4 and 5. Polymerizable material 81 may be sprayed against strands 29' and 29'' by spray nozzles 80 and may then be similarly carried into the bite of the rolls. Any one or two of the warps may be omitted as illustrated for example in FIGURE 3 in which only warp 50 is provided and in FIGURE 4 in which only warp 60 is provided. Between rolls 36 and 37 the said polymerizable materials may be polymerized by the application of heat thereto, which may be accomplished for example by heating rolls 36 and 37. Alternatively the polymerizable material may in this manner be only partially polymerized to an extent sufficient to at least attach the strands together to thereby provide a material which may be subsequently fully polymerized to form a finished sheet article without further maintenance of tension by means external to the material.

In order to prevent adherence of the polymerizable material or the resultant polymerized synthetic resin to the surface of either roll 36 or 37, sheets 82 and 83 of a material which is not adherent to the polymerizable material used may be interposed between the surfaces of the rolls and the said polymerizable material. This may be accomplished in the manner shown by providing such a sheet 82 which may travel around idler roll 84 and around roll 36 and by providing such a sheet 83 which may travel around idler roll 85 and around roll 37. The material of which sheets 82 and 83 may be made is not critical and may be any film or sheet material which is no adherent to the polymerizable material used and resulting polymeric material used; for example, cellulose acetate, regenerated cellulose or a polymer of terephthalic acid and glycol are suitable for use with many polyesters.

As the laminated non-woven fabric sheet 5 passes from rolls 36 and 37 it is still attached to cables 30 by virtue of strands 29 which still extend therearound. It may be detached from cables 30 by rotating knives 97 operating against walls of grooves 38' at the edge of roll 38 in the manner shown in FIGURE 2. It may then pass over one or more suitable idler rolls such as roll 98 and may then be wound up on a wind-up roll such as roll 99.

Prior to being wound up on wind-up or storage roll such as roll 99, sheet 5 may be subjected to suitable finishing treatments. For example, it may be passed through a calender or may be passed through an oven; it may be passed through a festoon oven in order to accomplish the completion of polymerization or in order to dry the material; it may have one or more protective, decorative or photo-sensitive coatings applied thereto; it may be printed upon; it may be embossed or it may be supplied with any one of various sorts of surface finishes such as a roughened drafting surface, a damascened surface or a pearlescent surface by any one of the techniques known to the art such as embossing, printing and the like.

Tension is maintained in the strands in warps 50, 60 and 70 or any one or two of the warp beams which is used, at the point of lamination, that is particularly at the bite of rolls 36 and 37. This may be accomplished by suitable drive means (not shown) interconnecting with drive rolls which are not shown and may be interposed between roll 38 and roll 99 and be adapted to pull the warp beams through between rolls 36 and 37 or it may be accomplished by drive means (not shown) operating upon wind-up roll 99 or such tension may be maintained by means of some of the aforementioned idler rolls such as 51, 55, 57, 61, 65, 67, 71 and 75 or other rolls over which warp beams 50, 60, and/or 70 may pass—operating in conjunction with said wind-up or drive-roll means.

Tension may be maintained in strands 29 at the aforesaid place of lamination by cables 30 which tend to be pulled inwardly when the strands 29' and 29'' are forced closer together by rolls 36 and 37 as they pass off table 31 and are prevented from being pulled together in this manner by the outer marginal portions 36' and 37' of the ends of said rolls against which cables 30 are pulled

inwardly because the space between the cylindrical surfaces of the rolls is insufficient to allow cables 30 to pass therethrough. If desired, grooves 36" and 37" may be provided at the peripheral edges of rolls 36 and 37 to support cables 30 and prevent cables 30 from being forced upwardly or downwardly to an undoing extent alongside the bite of rolls 36 or 37 by minor variations of tensile stress in strands but tension may adequately be provided in strands 29 without the provision of said grooves.

This is shown in greater detail in FIGURE 6 which is a transverse cross section taken at the bite of the rolls 36 and 37 with all strands and polymerizable material removed therefrom.

The portions 29a of strands 29 which surround cables 30 prior to the cutting loose of these portions from sheet 5 by knives 97, continue to encircle cables 30 as they pass about roll 38 and such portions 29a may be removed from cables 30 by strippers 39. Each of strippers 39 may be a blade-like device as shown or may be a stationary brush or a rotating brush provided with either metal or organic bristles or may be any other suitable means for removing short strand sections.

As shown in FIGURE 3, warp beams 60 and 70 may be omitted and the strands of warp 50 may be brought into adjacency with strands 29" substantially at the bite of rolls 36 and 37 and at the same place, strands 29' may be brought into adjacency with strands 29". Strands 29' may form a separate layer from strands 29" as shown or strands 29' may be interposed between strands 29".

As shown in FIGURE 4, three planar layers of strands are superposed and attached together with polymeric material, strands in each layer being substantially parallel and the planes of the layers being substantially parallel, warp 50 and 70 being omitted.

As shown in FIGURE 5, the strands of warps 50, 60 and 70 may be brought into adjacency with strands 29' and 29" substantially at the bite of rolls 36 and 37. Thus are formed five layers of strands superposed on one another and attached together with polymeric material, strands in each layer being at least substantially parallel to one another and the planes of the layers being parallel to one another, the strands in each layer crossing strands in adjacent layers at an angle which as shown may be about 90°.

It is of course clear that polymerizable materials 53, 63 and 73 and 81 may be identical with one another or may be different from one another so long as they are compatible. Furthermore, it is believed clear that these materials need not necessarily be applied in the manner shown by either dipping or spraying but may be applied with doctor blades or troughs or in any other suitable manner. For example, warp beam 60 need not pass through bath 64 at all, but sufficient polymerizable material may be applied to both the strands of warp 60 and strands 29' by sprayers 80.

In place of warp 60, a sheet of thermoplastic synthetic resin, adapted to be easily tackified by heat, may be introduced between strands 29' and 29". When such a sheet passes between rolls 36 and 37 it may become tacky by absorption of heat from the rolls and the pressure of rolls 36 and 37 may force strands 29' and 29" into the surfaces of the resin sheet whereupon they become secured together by synthetic resin when the sheet cools. Material for such a sheet may preferably be polyethylene, polypropylene, a polymer or copolymer formed from one or more of vinyl acetate, vinyl alcohol, vinyl chloride, vinylidene chloride, a polyvinyl acetal such as polyvinyl formal or polyvinyl butyral, a polyamide, a polyfluorohydrocarbon, a sulfone resin, a silicone resin, a polymer or copolymer of an ester of acrylic acid or methacrylic acid, a natural or synthetic rubber such as GR-S, GR-N, or other polymers or copolymers of butadiene, styrene and acrylonitrile, polyisobutylene, a styrenated polyester, or a cellulose derivative such as a cellulose ether, a cellulose

ester such as cellulose acetate or cellulose nitrate, or a mixed cellulose ester such as cellulose acetate butyrate or cellulose acetate propionate. Any other flexible or elastomeric thermoplastic resin may be suitable. Also, an incompletely polymerized sheet of thermosetting resin such as a polyester or phenolic resin may be very suitable. This may be tackified by heat or solvent and may subsequently be fully polymerized after strands are pressed into the surface thereof.

Referring now to FIGURE 7, there is shown another embodiment of the invention, in which two winders are provided, each of which carries two spools of yarn. Winder supporting rings 121 and 122 are securely attached to and supported by platform 123 to form the winder assembly indicated generally as 120 and are adapted to rotatably support winder rings 101 and 111. Platform 123 is provided with grooves, adjacent to two of its edges, to adapt it to slide upon ways 126 and 127 supported by means not shown.

Winder ring 101 may support upon brackets 107 and 107a spools 106 and 106a from which strands 29 and 29b may be lead off through eyelets 108 and 108a and thence through eyelets 109 and 109a to be wound around cables 130 adjacent to table 131.

Similarly, winder ring 111 may support spools 116 and 116a on brackets 117 and 117a from which strands may be lead off through eyelets 118 and 118a and thence through eyelets 119 and 119a (spool 116a, bracket 117a and eyelets 118, 118a, 119 and 119a not being shown in FIGURE 7).

The purpose of providing two winder assemblies is to permit an operator to reload empty spools on one winder while the other winder is operating. Since the operating winder must preferably be in the same position at all times with respect to cables 130 and table 131, means are provided to shift winder assembly 120 back and forth so that the winder which is operating may always be in the same position. Thus as shown in FIGURE 7, winder ring 101 may be operating and winder ring 111 may be stopped to permit loading. At such time as spools 106 and 106a become empty, pin 128 may be pulled upward to release platform 123 and assembly 120 may then slide on ways 126 and 127 until ring 122 is in a position shown as being occupied by ring 121, whereupon the assembly 120 may be locked in this position by inserting pin 128 through hole 128' in platform 123.

Ring 101 may be rotated by motor 113 acting through clutch 124 to drive spur gear 104 which may act upon ring gear 105 attached to ring 101 and winder ring 111 may be rotated by motor 113 acting through clutch 125 to drive spur gear 114 which may act on ring gear 115 attached to ring 111. When the assembly 120 is in the position shown in FIGURE 7, clutch 125 may be released to allow ring 111 to be stopped so that spools 116 and 116a may be reloaded and clutch 124 may be engaged in order that winder ring 101 may operate. Similarly, when assembly 120 is in the other operative position so that ring 122 is in the position shown as being occupied by ring 121, clutch 124 may be released and clutch 125 may be engaged to cause ring 101 to be stopped so that spools 106 and 106a may be reloaded and cause ring 111 to operate.

As shown in FIGURE 8, a winder ring such as ring 111 may be supported in a supporting ring such as ring 122a by roller bearings 112 and roller bearings 112' and instead of being driven through spur gears may be driven by a bevel gear such as 114a operating against a bevel ring gear such as 115a attached firmly to ring 111. Roller bearings 112' may be retained in place by retainer ring 122b secured to ring 122a by means such as studs 122c.

Cables 130, which may be jacketed as described in connection with cables 30, are guided through rings 101 and 111 by grooves 132 in the edges of table 131. The width of table 131 may be adjusted by means of bolts 133, each of which may have left hand threads on one end and right hand threads on the other or by other suit-

able means. Table 131 may be hingeably supported at one end by shafts 134 supported by journals not shown and may be supported at its other end by roller 135.

Cables 130 may travel endlessly clockwise passing in turn alongside table 131, thence alongside the bite of laminating elements 136 and 137, thence over sheaves 138, thence through strippers 39 and thence in turn over sheaves 140, sheaves 141, sheaves 142, sheaves 148 on shaft 149, sheaves 144 on shaft 145 and thence again alongside table 131. Cables 130 may be caused to travel in the manner described by means of motor 146 or other constant driving means driving a pair of sheaves such as sheaves 148 mounted on common shaft 149 through a suitable gear reduction such as 147. Gear reduction 147 may be a constant speed reduction such as, for example, a pair of meshing spur gears, or it may be a gear reduction adapted to provide intermittent motion of cables 130, as shown in FIGURES 6 and 7, for reasons hereafter more fully described. If desired, sheaves 148 may be mounted on separate shafts or otherwise independently, but in any event it is desirable that means be provided to cause sheaves 148 to move at all times at the same rate of speed and therefore to drive both of cables 130 at the same rate of speed.

As either winder ring 101 or 111 rotates, strands 29 and 129 are wound around table 131 and juxtaposed cables 130 so as to form two layers of strands, with one layer being above table 131 and the other being below table 131 as cables 130 move forward, and the cables may carry with them these layers of strands into the bite of the laminating elements 136 and 137. The strands in the layer above the table are designated 129' and those below the table are designated 129''.

Warp 50 may be built on a continuous warp machine of the type well known to the art. It may then pass over a suitable direction changing idler roll such as 51 and thence over an idler roll such as 52 immersed in liquid polymerizable material 81 contained in bath 54 and may thence pass between a pair of wiper blades 155 and 156 adapted to remove excess polymerizable material 81 from the warp and may thence pass over idler roll 157 and enter into the bite of laminating elements 136 and 137, where it may come into conjunction from below with strands 29'. Warp beam 50 is thus caused to carry polymerizable material 81 into the bite of laminating elements 136 and 137. Additional polymerizable material may be supplied by spraying of material 81 from spray manifold 80 against strands 129'.

Polymerizable material 81 may be any material which may be polymerized to form a synthetic resin and is generally preferably adapted to polymerize to form a flexible resin; polyester resins have been found suitable.

Because polymerizable material 81 may be tacky, viscous and adherent to metal surfaces, it may often be desirable to provide sheets 182 and 183 interposed respectively between each of the two surfaces of the material being laminated and the laminating elements to prevent adherence of the partially polymerized material to the laminating elements. The material of which sheets 182 and 183 may be made is not critical and may be any sheet material which is not adherent to the polymerizable material and resulting polymeric material used, as discussed above in connection with sheets 82 and 83.

Sheet 182 may consist of an endless belt-like sheet travelling continuously clockwise, first passing over the upper surface of the lower laminating element 136, thence over direction changing idler rolls 184, 185 and 186 and thence again over the surface of element 136.

Similarly, sheet 183 may be an endless belt-like sheet and may travel continuously counter-clockwise between laminating element 137 and the material being laminated, and thence over idler and direction changing rolls 187, 188, 189, 190, 191 and 192 and thence again around laminating element 137.

In order to provide necessary or desired tension in

strands 129' and 129'' as material 81 is polymerized while the assembly traverses the upper surface of laminating element 136, tension may be provided in cables 130 to thus pull said strands crosswise across the upper surface of element 136 and the cables may also maintain tension in the strands in the manner discussed in connection with cables 30.

In order to provide the desired pressure against the material 81 during its polymerization, metal sheet 193 may be provided which may travel around laminating element 137 thence above laminating element 136 and thence around rolls 187, 194, 195 and 196. By providing a suitable degree of tension in endless metal sheet 193, it is caused to be stretched over the upper surface of laminating element 136 and thereby to provide pressure against the material being polymerized between 193 and 136.

Laminating element 136 may be a shoe as shown or may be a roll. Both of the laminating elements may be heated by any suitable means, such as for example, by steam or electric heaters. Grooves 136' and 137' may be provided at the peripheral margins of elements 136 and 137 in order to cause cables 130 to travel in the desired relationship to the edges 136 and 137, as shown in greater detail in FIGURES 22 to 30.

After being laminated the completed sheet article 6 is still attached to cables 130 by virtue of strands 129 which still extend therearound. It may be detached from cable 130 by rotating knives 197 operating against peripheral edges of sheaves 138 in the manner shown in FIGURE 9. The residual portions 129a of strands 129 which then remain disposed around cables 130 may be removed therefrom by means of strippers 39.

The completed sheet article 6 may then pass over one or more idler or direction-changing rolls such as 198 and may then be wound up on storage roll 199 or may first be subjected to additional treatments as described above for sheet 5, adapted to produce desired surface finishes or to complete the polymerization of the synthetic resin.

When only a single spool of yarn, from which a single strand is taken off, is passed continuously repeatedly around cables 30 or 130 and interposed table 31 or 131, the strand is laid down in such a manner as to have the appearance shown in FIGURE 10 and when layers of strands built in this manner are brought into conjunction with a warp and laminated with a transparent synthetic resin, the completed non-woven fabric has the appearance shown in FIGURE 11. Table 31' shown in FIGURE 10 differs from table 31 in not being provided with means for adjusting its width. The strands in each layer are parallel or substantially parallel to each other, those in the upper and lower layers of cross-wise strands are almost parallel or at least substantially parallel to one another.

However, when two spools and therefore two strands are wound simultaneously around the cables and the table, as shown in FIGURE 7, the strands are laid down in such a manner as to appear as shown in FIGURE 12 and when such layers are brought into conjunction with a warp and laminated with a transparent synthetic resin, the completed fabric sheet appears as shown in FIGURE 13. The strands in each layer are parallel or substantially parallel to one another but the strands in the upper and lower cross-wise layers are essentially non-parallel, although they may be substantially parallel if the distance between cables is wide during winding and the diameter of the strands is small. In any event, the strands in one layer cross over those in the other layer at an acute angle and this may be unsuitable in some instances.

By causing cables 130 to move forward with an intermittent motion so that as strands 29 and 29b are laid down against surfaces of table 131', the cables do not move, and as strands 29 and 29b are laid down against cables 130, the cables travel forward, the arrangement of FIGURE 14 and (by laminating with transparent resin) the non-woven fabric 8, as shown in FIGURE 15,

may be produced. All the crosswise strands in fabric 8 are parallel. Table 131' differs from table 130 in the same way table 31' differs from table 30.

Also by causing the operating winder to traverse so that it moves in the same direction and at the same speed as cables 130, as strands 29 and 29b are laid against surfaces of table 131', and traverses in an opposite direction while strands 29 and 29b are laid down against cables 130 and cables 130 themselves continue to travel forward at a continuous rate, the arrangement shown in FIGURE 14 and the fabric 8 of FIGURE 15 may be produced.

By causing the cables 130 to move forward with a partially intermittent motion so that as strands 29 and 29b are laid down against surfaces of table 131', cables 130 travel forward slowly and as strands 29 and 29b are laid down against cables 130, the cables travel forward relatively rapidly, with the winder meanwhile rotating at a continuous speed, the arrangement shown in FIGURE 16 may be produced and with this arrangement of crosswise strands and a warp the fabric 9 illustrated in FIGURE 17 may be produced.

Similarly by causing the operating winder to traverse in such a manner that as strands 29 and 29b are laid down against surfaces of table 131' the winder traverses in the same direction as cables 130 but at a somewhat lower rate of speed and as strands 29 and 29b are laid down against table 131', the operating winder is caused to traverse in the opposite direction, the arrangement of strands 29 and 29b around cables 130 and table 131' shown in FIGURE 16 may be produced and with this arrangement the fabric 9 may be made. It will be noted that in fabric 9 the crosswise strands are not parallel to one another but are at least substantially parallel to one another and that there is no objectionable crossing over of the crosswise strands.

In order to provide fully intermittent forward motion of cables 130, which may be utilized to provide the arrangement of FIGURE 14 and therefrom the fabric 8 shown in FIGURE 15, the gear reduction 147 may be replaced with a Geneva movement as shown in FIGURE 18. Motor 146 may drive, through bevel gears 401 and 402, a Geneva gear 403 firmly attached to a shaft to which gear 402 is attached. Each time the single tooth 404 of Geneva gear 403 engages one of the slots 405 in Geneva gear 406, gear 406 is caused to rotate and at such times as tooth 404 is not thus engaged, the periphery 407 of Geneva gear 403 is seated against one of the concave portions 408 of Geneva gear 406, thus preventing motion of gear 406. Thus, each time gear 403 makes a single revolution, gear 406 is caused to revolve an amount equal to the distance between a pair of slots 405. Gear 406 may be firmly attached to a shaft to which spur gear 409 is also firmly attached and spur gear 409 may drive a spur gear 410 attached to sheave 148 around which cable 130 passes.

Cables 130 may be caused to move forward with a different sort of intermittent motion so as to lay down strands 29 and 29b to form the arrangement shown in FIGURE 16 and thus to provide fabric 9 by substituting for gear reduction 147 in FIGURE 7 the chain of gears indicated generally as 411 shown in FIGURE 19. This gear chain may consist of bevel gears 412 and 413 driven by motor 146. Elliptical gear 414, attached to bevel gear 413 may drive elliptical gear 415. Spur gear 416 attached to elliptical gear 415 may drive spur gear 417 attached to sheave 148 over which cable 130 may pass and thus motor 146 may cause cable 130 to move forward with a rate of speed varying in a manner determined by the elliptical gears 414 and 415.

Oscillatory traversing of the operating winder may be provided by the crank means indicated generally as 420 shown in FIGURE 20. (As shown therein, winder rings 101' and 111' may have a somewhat different cross section than do winder rings 101 and 111 as shown in FIGURES 7 and 8.)

Motor 421, mounted on stationary support 422 may drive bevel gear 424 through bevel gear 423. Bevel gear 424 may be provided with pin 425 perpendicular to the plane in which it rotates and permanently attached to one of its faces at a point other than its axis of rotation. Crank arm 426 may be hingeably attached to platform 123 at 427 and may be provided with holes 428 and 429 adapted to fit over pin 425. When motor 421 is operated, gear 424 rotates and causes crank arm 426 to operate with a connecting-rod-motion thus causing platform 123 and the winder supported therefrom to traverse back and forth, with an oscillatory motion. As shown in FIGURE 20, the position of platform 123 and the winder supported thereby corresponds to that shown in FIGURE 7. When it is desired that winder ring 101' be stopped in order to permit reloading and therefore to operate winder ring 111' while ring 101' is being reloaded with fresh spools, crank arm 426 may be disengaged from pin 425 at hole 428, platform 123 may be slid along ways 126 and 127, and crank arm 426 may then be re-engaged with pin 425 at hole 429.

As shown in FIGURE 21, cam means indicated generally as 430 may be utilized to cause winder platform 123 to traverse with an oscillatory motion and in this way any sort of oscillation may be provided whereas the crank means 420 is limited to the production of a single type of oscillatory motion. Motor 431 may be mounted on sliding support 432 which may slide upon support 445 at the end of ways 126 and 127 and may drive bevel gear 434 through bevel gear 433. Cam 435 may be attached to bevel gear 434 and may operate against push rod 436 which may be attached to platform 123 at 437. Pushrod 436 may be urged against the surface of cam 435 by spring 438 mounted on extension 439 of support 432 and compressively engaging collar 440 which may be securely attached to pushrod 436. In order to provide for shifting the position of platform 123 and thereby shifting winder assembly 120 and in order to allow winder ring 101' to be stopped and to allow winder ring 111' to operate, holes 441 and 442 may be provided in support 445. Pin 443, which may extend downward through hole 444 in support 432 and thence downward into hole 441, may be pulled upward, and platform 123 may be slid along ways 126 and 127 until pin 443 may be engaged in hole 442, whereupon ring 111' will be in position to operate. With cam means 430, oscillatory traversing of winder assembly 120 may be provided in such manner as to produce either fabric 8 or fabric 9.

As shown in FIGURE 22, laminating elements 137 and 136 (and equally well, laminating elements 36 and 37 and other laminating elements hereinafter described) may be provided with grooves 137' and 136' having the form of a quarter of a circle and thereby being adapted to fit snugly against strands 29 disposed around one of endless flexible members 130. As shown in FIGURES 23 and 24, the same form of grooves may be utilized when a warp beam such as warp beam 60 is laid between upper and lower layers of fibers 29 instead of being laid below fibers 29 as is warp beam 50 as shown in FIGURE 22, or when three warp beams 50, 60, and 70 are provided as shown in FIGURE 24.

As shown in FIGURE 25 the grooves need not necessarily have the form of circles in order to allow cable 130 to travel alongside and against the sides of the laminating elements and to prevent inward movement of the cables toward each other and, in fact this may suitably be accomplished without any grooves whatever as shown in FIGURE 30.

As shown in FIGURES 26 and 27, such inward movement of the endless flexible members may be prevented by making the face width of one of the laminating elements greater than the face width of the other. As shown, the face width of the laminating elements 137b and 137c is greater than that respectively of 136b and 136c. As shown in FIGURE 27 grooves 136c' may be provided at the edge of the laminating element having the lesser face

width in order to more suitably maintain the cable at exactly the position desired.

As shown in FIGURES 28 and 29, inward movement of the cables across the surface of laminating elements such as 136d or 136c (or 136 as shown in FIGURE 7) may be prevented in whole or in part by providing sheaves or rollers of narrow face width such as 137d and 137e. Sheave or roller 137d is provided with a groove 137d' at its edge which corresponds to groove 137' as shown in FIGURES 22 to 24 and is thus adapted to cause cable 130 to remain seated in groove 136d' in laminating element 136d. Roller 137e which has a narrow face width may similarly be utilized to prevent movement of member 130 across the face of laminating element 136e.

It may be seen that the variety of the modifications shown in FIGURES 22 to 30 indicates that the invention is not restricted to any particular form of grooves at the edges of the laminating elements. The invention, rather, relates broadly to endless moveable flexible elements, such as chains, belts, cables, which travel alongside the bite of mating laminating elements and/or travel along the sides adjacent the edges of either shoe or roll laminating elements such as 136 which do not have other laminating elements mating therewith (except perhaps an endless metal belt) whereby said members are forced outwardly from each other and thereby maintain tension in strands such as strands 29 wound about the pair of endless flexible members. The outward force tending to hold said cables apart may be exerted primarily in either or both of two ways: (1) mating laminating elements interposed between the cables exert an outward force on the cables, resisting inwardly acting force tending to draw the cables together applied by strands such as strands 29 wrapped therearound, said inwardly acting force being caused by said laminating elements acting on said strands to force two layers of said strands together and to thereby shorten the effective length of said strands, (2) tension in the endless moveable flexible members as they move in an arcuate path alongside the edges of a laminating element causes said moveable flexible members to tend to move toward the center of curvature of said arcuate paths and to thereby exert outwardly directed force in opposition to the inwardly directed force exerted on said cables by strands such as strands 29 wound therearound.

Referring now to FIGURE 31 wherein is shown another embodiment, winders 221 and 222 are adapted to wind strands around endless moveable members 230 held apart and in substantially parallel relationship by interposed means 231 supported by shafts 234 attached thereto. Winders 221 and 222 may operate alternatively in the same manner as winders 101 and 111. Strands 29 wound around endless members 230 are carried downward through a bath of polymerizable material 81 contained in tank 279 and excess polymerizable material is removed therefrom by squeeze rolls 255 and 256. Strands 29 are then carried into the bite of laminating elements 236 and 237 by endless members 230. At the bite of said rolls the strands 29 are brought into conjunction with warp beam 250 which may have been sprayed with polymerizable material 81 by spray nozzles 280 and may have passed over idler roll 257. Strands 29 and 250, thus impregnated or partially impregnated with polymerizable material 81 may then pass over laminating roll 236, being interposed between the surface of said roll and endless metal sheet 293. Strands 29 may be maintained in tension as they pass around the periphery of laminating roll 236 by the tendency of members 230, which may be maintained in tension, to assume a shorter path as a result of the maintenance of such tension. As the strands are carried around the periphery of roll 236, polymerizable material 81 may be cured (polymerized) by the application of heat thereto by any suitable means, such as by

heating roll 236 or by applying heat from radiant sources not shown or both. Members 230 pass alongside the bite of laminating elements 236 and 237 and are maintained in the desired substantially parallel spaced relation by abutting against the sides of these laminating rolls and are maintained in similar relationship as they travel in conjunction with the periphery of roll 236 by the interaction of the aforesaid force tending to cause them to assume a shorter path and the restraining force exerted upon them by strands 29. Strands 29 and 250 may then pass between rolls 236 and 287 while members 230 pass along the bite of said two rolls and the strands and members 230 may then pass over and alongside respectively of the surface of roll 287 and thence to sheaves 238 and rotating cutter blades 297 which may interact to sever members 230 from completed sheet material 6 in the same manner as shown in FIGURE 9 for rotating cutters 197 and sheaves 138. Material 6 consisting of strands 29 and 250 secured together with polymerizable material 81 may then be wound up on roll 299. Endless member 230 may then pass over sheaves 238 and through strippers 39 adapted to remove ends 29a therefrom and thence over sheaves 244 again into conjunction with interposed means 231 adapted to maintain members 230 parallel or substantially parallel while strands 29 are wound therearound.

To provide a smooth flat surface on the side of sheet material 6 opposite the surface of laminating roll 236 and to provide pressure against said surface during lamination of said material an endless metal sheet 293 may be provided which may pass over roll 237 and thence into the bite of rolls 236 and 237 where it comes into conjunction with strands 29, strands 250 and polymerizable material 81. It may then pass over the periphery of roll 236 in conjunction with the material being laminated and thence over roll 287 and thence over idler rolls 294 and 295 and 296 and again into conjunction with roll 237.

To prevent adherence of material 81 in either the unpolymerized or partially polymerized or fully polymerized states, to the metal surfaces of either sheet 293 or roll 236, sheets 282 and 283 may be provided. These may be of the same materials or same sort of materials as described in connection with sheets 182 and 183, and may serve the same purposes. Sheet 282 may pass over roll 236 and idler 284. Sheet 283 may pass through the bite of rolls 236 and 237 and thence through the bite of rolls 236 and 287 and thence over idler rolls 288, 289, 290 and 291 and again into conjunction with roll 237.

In FIGURES 32, 33, 34 and 35 are illustrated several possible physical arrangements of some of the principal elements of the device illustrated in FIGURE 31. FIGURE 33 illustrates the same arrangement which is shown in FIGURE 31. FIGURES 32, 34 and 35 illustrate other arrangements.

The motion of members 230 may be intermittent or partially intermittent for the same reasons and to accomplish the same reasons and to accomplish the same objectives as described above in connection with such motion of members 130. Also winder 221 or winder 222 may be caused to traverse with an oscillatory motion as described in connection with winder assembly 120 for the same reasons to accomplish the same objectives.

Referring now to FIGURE 36 there is shown another embodiment in which the objectives desired to be achieved by intermittent motion of members 130 or 230 or oscillatory motion of winders 120, 221 or 222 may be accomplished without any such back-and-forth motion, the motion of members 330 and winder assembly 310 illustrated in FIGURE 36 being non-intermittent and non-oscillatory. As illustrated in FIGURE 36, endless, moveable, flexible members 330 engage with interposed means 331 and pass against laminating elements 336 and 337 and against roll 387 and over sheaves 338 and 344 in

the manner and for the reasons described in connection with members 130 and 230. Interposed table 331 is provided with grooves 332 in its edges and with adjusting means 333 and with supporting means 334 in the same manner and for the same purposes as described in connection with elements 131 and 231. Grooves 332 in the edges of platform 331 may be lubricated to facilitate the sliding of members 330 therein in the manner described in connection with members 30 and grooves 32.

The winder indicated generally as 310 may consist of a ring 311 adapted to rotate on a plurality of rollers 312 which may be supported on pins 314 attached to supporting bracket 313, which in turn is supported by supporting arms 315, which in turn are supported by means not shown. Ring 311 may be provided with spools or cops 316 rotatably mounted on the upper surface thereof. Strands 29 may pass from cops 316 through eyelets 318 supported above the cops by brackets 317 and may then pass through eyelets 319 in guide plate 320 and may then pass into conjunction with endless flexible members 330 and interposed platform 331, around which they are wound as ring 311 is turned. Ring 311 may be turned by any suitable means, such as for example, motors contained in rolls 312 or by a ring gear attached to the outer edge of ring 311, which may be driven by a motor through a spur or bevel gear.

Warps 350 and 370 may pass over idler rolls 351 and 371 and then over rolls 352 and 372 immersed in liquid polymerizable material 81 contained in bath 354 and may thus be impregnated with polymerizable material 81. Warp 350 may then pass over idler roll 355 and then into conjunction with strands 29 at the bite of rolls 336 and 337. Warp 370 may pass over idler rolls 375, 376, 378 and 379 and then into conjunction with strands 29 at the bite of rolls 336 and 337. Resin 81 may be applied to strands 29 by spray nozzles 380.

To avoid producing a material in which one layer of strands 29 crosses another layer of strands 29 at an acute angle, endless metal sheet 360 may be interposed between the two layers of strands 29. Sheet 360 may be disposed adjacent one surface of platform 331 where strands 29 are wrapped around members 330 and platform 331 so that strands 29 are in fact wrapped around cables 330, platform 331 and sheet 360. Sheet 360 may then pass upward through the bite of rolls 336 and 337 and may then pass over roll 336 in conjunction with warps 350 and 370 and strands 29. As it does so it may act to separate warp 370 and one layer of strands 29 on one side from warp 350 and the other layer of strands 29 on the other side and to thus provide two separate and distinct sheets of material.

Endless metal sheet 393 may be provided in the same manner and to serve the same purposes as sheets 193 and 293. It may pass over roll 337, thence over roll 336, thence over roll 387 and then over idler rolls 394, 395 and 396 back into conjunction with roll 337. Rolls 339 and 339' may be provided acting against the outer surface of sheet 393 immediately following roll 337 to exert additional pressure on the material being laminated.

Spray nozzles 367 may spray a mold release agent against the surface of sheet 393 which is in contact with the laminate to prevent adhesion and sticking between the laminate and sheet 393. Similarly, spray nozzle 368 may be provided to spray a mold release agent against the surface of roll 336 to prevent adherence to said surface. Members 330 may be severed from the completed sheet material by the action of rotating blades 397 acting against sheaves 338 in the manner described heretofore in connection with cutter blades 197 and sheaves 138. The material may then pass between rolls 398 and 398'. The sheet of material 7 on one side of sheet 360 may then be wound up on windup roll 398' and the sheet of material 7' on the other side of sheet 360 may then be wound up on wind-up roll 399'. Materials 7 and 7' thus each consist of one warp and one layer of strands 29 bonded together with synthetic resin. Sheet 360 may

then pass downward over roll 361 and may then pass over roll 362 having its axis at 45° to that of roll 361, whereupon it passes to one side of the machine and may then pass over rolls 363 and 364, and thence over roll 365 adapted to bring it again into conjunction with a surface of platform 331. It is necessary to run sheet 360 around the side of the machine in this manner to avoid conflict with warps 350 and 370. Alternatively, warps 350 and 370 may be brought in from one side of the machine and if this is done it may not be necessary to run sheet 360 around the side of the machine.

In FIGURE 37 there is shown schematically another embodiment of the device of the invention. The winder assembly indicated generally by the numeral 510 may consist of winder rings 511 and 512 supported on winder supporting frame 513. Winder supporting frame 513 may be supported by actuating arms 514 attached to pistons in hydraulic cylinders 515 which may be supported by means not shown. Winder ring 512 may be rotatably supported on bearings at the ends of arms 513a extending from winder supporting frame 513 and winder ring 511 may be rotatably supported on bearings on the ends of arms 513b extending from winder supporting frame 513. Winder ring 511 may carry spools 516 which may rotate on shafts 517. Winder ring 512 may carry spools 518 which may rotate on shafts 519. Strands 29 from spools 516 may pass through eyelets 520 in eyelet plate 521 attached to ring 511. Strands from spools 518 may pass through eyelets 523 in eyelet plate 524 attached to ring 512. The strands of yarn 29 unwinding from spools 516 may pass repeatedly around a pair of substantially parallel portions of endless moveable flexible members which may be belts 530. Belts 530 may pass through winder rings 511 and 512 and may be held in the desired parallel relationship by interposed means such as table 531 provided with concave grooves 532 at its edges in which members 530 may slide. To facilitate sliding of members 530 in grooves 532, the grooves may be lubricated with any viscous oily material compatible with the synthetic resin or resins subsequently utilized to attach crossing layers of strands together or even with a non-compatible lubricant which may be a suitable mineral oil or the like. Members 530 may be of any suitable material such as one or more steel or stainless steel strands and may, if desired, be jacketed with a yieldable material such as natural or synthetic rubber or a synthetic resin such as for example, a polyester, a polyamide, or a polytrifluorochloroethylene or a silicone or polytetrafluoroethylene, to provide a smooth surface and thus to lessen the possibility of breaking the strands. They may have a construction similar to that of V-belts but may have a round or oval cross section.

Table 531 may be provided with means such as turn-buckle-like adjusting bolts 533, to adjust its width and to thus provide a slightly greater width at one end or the other as may be found necessary in operation or to vary the average width as may be found necessary under varying circumstances to provide the proper tension on strands 29 wrapped therearound. Other suitable means for varying the width may be used.

Table 531 may be hingeably mounted near the end with which members 530 first become engaged by means of shafts 534 which may rotate in journals which are not shown or may be supported by any other suitable means. Members 530 may travel forward endlessly (in a clockwise manner as viewed in FIGURE 37) passing in turn alongside table 531, thence alongside the bite of laminating rolls 536 and 537, thence alongside the peripheral edges of the large roll 536, thence alongside the bite of rolls 536 and 587, thence over grooves 587' in roll 587, thence over grooves 538' in roll 538, thence through strippers 39, thence over sheaves 540, thence over sheaves 544 and thence again alongside table 531. If desired, roll 587 may be supplanted with sheaves such as 540. Sheaves 540 and 544, which are idlers, need not necessarily be mounted on common shafts. Belts 530 may be

caused to travel in the manner described by means of motor 546 or other constant driving means driving roll 538 or sheaves through shaft 547, either directly as shown or through any suitable gear reduction.

As winder ring 511 rotates, strands 29 are wound around table 531 and juxtaposed members 530 so as to form two layers of strands, one layer being on one side of table 531 and the other being on the other side of table 531. As members 530 move in the manner described above they may carry with them the layers of strands thus built-up into the bite of rolls 536 and 537.

The purpose of providing two winder rings is to permit an operator to reload empty spools on one winder ring while the other winder ring is operating. Since the operating winder ring must preferably be in the same position at all times with respect to members 530 and table 531, means are provided to shift winder assembly 510 back and forth so that the winder ring which is operating may always be in the same position. Thus as shown in FIGURE 37, winder ring 511 may be operating and winder ring 512 may be stopped to permit loading. At such time as spools 516 become empty, winder assembly 510 may be elevated by supplying hydraulic fluid to hydraulic cylinders 515 by any suitable means of the types well known in the art, in order to bring winder ring 512 into the position shown in FIGURE 37 as being occupied by winder ring 511.

Ring 511 may be rotated by motor 526, attached to supporting frame 513 acting through clutch 527 to drive spur gear 504 which may act upon ring gear teeth 505 on winder ring 511, and winder ring 512 may be rotated by motor 526 acting through clutch 528 to drive spur gear 506 which may act upon ring gear teeth 507 on ring 512. When the assembly 510 is in the position shown in FIGURE 37, clutch 528 may be released to allow winder ring 512 to be stopped so that spools 517 may be reloaded and clutch 527 may be engaged in order that winder ring 511 may operate. Similarly, when assembly 510 is in the other operative position so that winder ring 512 is in the position shown as being occupied by ring 511, clutch 527 may be released and clutch 528 may be engaged to cause ring 511 to be stopped so that spools 516 may be reloaded and to cause ring 512 to operate.

Polymerizable material 81 may be applied to strands 29 by allowing said strands to pass through a quantity of polymerizable material 81 contained in a trough 579 surrounding members 530 and table 531. Excess polymerizable material 81 may be removed by flexible wiper blades 565 and 566 adapted to exert a wiping action against strands 29.

At the bite of rolls 536 and 537, strands 29 may be slidably removed from table 531 and may be brought into conjunction and pressed together to form a material involving two layers of strands in which the strands in each layer are parallel but in which the strands in one layer are not parallel to those in the other and heat and pressure may be applied to polymerize such polymerizable material and bind strands 29 together. Heat may be supplied by heating roll 536 or in any other suitable manner. Pressure may be supplied by means of endless metal sheet 593 which may be adapted to travel endlessly over a large portion of the surface of roll 536 in conjunction with strands 29 and polymerizable material 81 while said polymerizable material is being polymerized. Metal sheet 593 may pass under roll 537, over roll 536, under roll 587, and thence over idler rolls 594, 595 and 596, back to the beginning. By providing a suitable amount of tension in the metal belt-like sheet 593, the necessary pressure can be applied to the assembly of strands 29 and material 81 between the surfaces of rolls 536 and metal belt 593. In order to prevent sticking of tacky adherent polymerizable material 81 to the metal surfaces of roll 536 and belt 593, any suitable mold release agent may be applied to the outer surface of roll 536 and belt 593 respectively by spray nozzles 567 and spray nozzle 568.

Suitable means may be provided at the bottom of trough 579, between the two outer portions of table 531 to prevent leakage downward of material 81 there-through.

The completed laminated sheet article 8, as it passes off roll 587 has the appearance, if transparent synthetic resin is used, shown in plan view in FIGURE 38, being still attached to members 530 by those portions of strands 29 which still extend therearound. It may be detached from members 530 by rotating knives 597 operating against walls of grooves 538' at the edge of roll 538 in the manner described in connection with knives 197 and roll 138. It may then be wound up on wind-up or storage roll 599 or, prior thereto, sheet 8 may be subjected to suitable finishing treatments as hereinbefore described.

Tension may be maintained in strands 29, as they pass over roll 536 and during polymerization of material 81, by providing tension in members 530 which thus causes members 530 to be pulled inwardly towards the axis of roll 536 on both sides thereof and to thus stretch strands 29. Groove 536' may be provided at the peripheral edge of roll 536 in order to limit the extent to which members 530 are pulled inwardly in this manner. The angle, indicated as θ is FIGURE 38, which strands 29 make to members 530, may be varied by varying the number of spools carried by the winder rings and by either decreasing or increasing the speed of rotation of the operating winder ring accordingly or alternatively decreasing or increasing the speed of members 530. For example, angle θ may be decreased by providing a greater number of spools and thus winding a greater number of strands 29 simultaneously. In order to accomplish this the speed of the operating winder ring may be decreased or the speed of members 530 may be increased in order to provide a greater pitch.

The invention is equivalent to winding a warp beam around parallel spaced portions of a pair of endless cables with means interposed therebetween to provide the desired parallel relationship of the cables and the object of the invention may suitably be accomplished by building a warp on a warping machine of the type known to the art and causing such warping machine to repeatedly revolve around a pair of cables such as members 530 and interposed spacing means such as table 531, or by causing one or more warp beams built on such a machine to revolve in this manner.

Referring now to FIGURE 39 there is shown therein, in cross section, a machine comparable in most respects to that illustrated in FIGURE 37, in which most parts are identical with those of the machine illustrated in FIGURE 37 and serve identical purposes and are therefore identically numbered. Winder ring 512 is supported on bearings 502b rotatably mounted on arms 513a and its circular motion is defined by bearings 502a mounted on arms 513a. Winder ring 511 rotates on bearings 503b mounted on arms 513b and its circular motion is defined by bearings 502b mounted on arms 513b. Squeeze rolls 555 and 556 are adapted to remove excess polymerizable material 81 from strands 29 and are believed preferable to wiper blades 565 and 566. Adherence of material 81 in (either the unpolymerized state, the partially polymerized state or the fully polymerized state) to the surface of roll 536 or the adjacent surface of endless metal sheet 593 may be prevented by endless sheets 582 and 583 which may have the characteristics described heretofore in connection with sheets 382 and 383 and comparable sheets. Sheet 582 may pass over roll 536 and idler 584. Sheet 583 may pass over roll 537, thence through the bite of rolls 536 and 537, thence over roll 536, thence through the bite of rolls 536 and 587, thence over rolls 587, 588, 589, 590 and 591 and thence again over roll 537.

Referring now to FIGURE 40 there is illustrated a winder mechanism indicated generally as 710 which may take the place of winder mechanism 510. Rotating table 711 may serve as a winder ring and may be rotatably

mounted on rollers or roller bearings 723 mounted on piers 715 and may be caused to rotate by motor 726, driving spur gear 724, which may be engaged with ring gear 725 on the inner marginal edge of table 711. Spools or cops 716 may be mounted on the upper surface of table 711. Strands 29 may pass from cops 716 through eyelets 718 supported above cops 716 by brackets 717 and thence through eyelets 719 in guide plate 720 which, as shown, may have the form of a cylinder, and thence may pass repeatedly around members 530 and interposed spacing means 531. Guide plate 720 may be mounted as shown on rotating table 711. Rotating table 711 may be very large in size and may support a very large number of cops 716, that is it may support on the order of 2,000-10,000 of such spools or cops. In order to provide for continuous operation of the machine, rotating table 711 may travel at a very slow speed of rotation such as about 1 to 10 r.p.m. and the cops when the winder is initially placed in operation may consist of fully filled spindles, partially filled spindles and only very slightly filled spindles so that as the winder operates only a few spindles become empty at any one time. As these spindles become empty they may immediately be replaced by operating personnel who may stand on rotating platform 708 which may rotate at the same speed or approximately the same speed as rotating tables 711. Rotating platform 708 may be mounted on rollers or roller bearings 703 supported by piers 702 and may be provided with railings 707. Platform 708 may be caused to rotate by motor 706 acting upon spur gear 704 which may be engaged with ring gear 705 at the inside edge of platform 708. In order to avoid an undue amount of walking around platform 708 to replace empty cops with full cops at various locations on rotating table 711, one or more operating personnel may vary the speed of motor 706 by any suitable means (not shown) such as by a variable transformer or variable resistance in the supply circuit of motor 706 or by a variable drive at the output of the motor or the like and may thereby vary the rotational velocity of platform 708 so as to cause platform 708 to rotate at either a slightly greater speed or slightly lesser speed than that of table 711. Said personnel may thus cause themselves to be brought into any desired position with respect to the periphery of table 711. The desirability of providing platform means such as 708 to bring personnel into any desired position with respect to the periphery of table 711 may be recognized if it is noted that table 711, which may carry the large number of cops hereinbefore mentioned, may have an outside diameter of as much as 30 feet and may therefore have a circumference of possibly over 100 feet.

Referring now to FIGURE 41 there is illustrated another winder assembly 810 which may suitably replace winder assembly 510. Rotating table or platform 811 may be mounted on rollers or roller bearings 823 mounted on piers 815 and its upper surface may be flush with that of floor 814 of the building in which the device is housed. Winder ring 811 may be caused to rotate by motor 826 acting through spur gear 824 engaged with ring gear 825 on the inner edge of platform 811. A creel or a warp beam 816 may be mounted on platform 811 and the warp of strands 29 passing therefrom may be wound around members 530 and interposed spacing means 531. Operating personnel may stand and walk on platform 811 to operate and service the winder.

Winder assemblies 710 and 810 have been described as suitable for use in place of winder assembly 510 but either one of these winder assemblies or a similar winder assembly may be utilized in place of any one of the winder assemblies hereinbefore described which may operate in a generally horizontal plane surrounding vertically travelling parallelly spaced members such as 230, 330 or 530.

Referring now to FIGURE 42 there is illustrated schematically in cross section another embodiment of the

device, wherein two endless flexible members 630 serve the same purpose and operate in the same manner as members 530 and other similar members hereinbefore described. They pass respectively over sheaves 644, thence alongside the edges of interposed spacing means 631, thence along the edges of roll 637, thence alongside the bite of laminating rolls 636 and 637, thence alongside the edge of roll 636, thence alongside the bite of rolls 636 and 687, thence alongside the outer marginal edge of roll 687, thence over sheaves 638 and thence over sheaves 640 and 644 and again into conjunction with grooves in the edges of interposed means 631, which may be similar in nature and purpose to platform 531 or other such means interposed between endless flexible members as hereinbefore described. Winder assembly 610 may consist of any winder assembly hereinbefore described but may be preferably similar to winder assembly 810; it is adapted to wind strands 29 around members 630 and interposed spacing means 631. Hydraulic cylinder 637" may be adapted to press roll 637 against roll 636. Metal endless sheet 693 may pass over roll 637, thence over roll 636, thence over roll 687, thence over idler and tensioning roll 694 and thence again over roll 637 in the manner and for the purposes hereinbefore described in connection with sheet 593 and other similar endless metal sheets. Polymerizable material 81 may be applied to strands 29 by sprays 680; squeeze rolls 655 and 656 may remove excess polymerizable material 81 from strands 29. Polymerizable material 81 may be polymerized as it passes around roll 636 as a result of action of heat thereon. Said heat may be supplied by heating roll 636 and also by providing heating shoes 600 which may contain electric radiant heating units adapted to heat endless sheet 693. The completed sheet material 8 consisting of two crossing layers of strands 29 is shown in FIGURE 38, bonded together with polymerized material 81, may be severed from members 630 by the cutting action of sheaves 638 against the outer marginal edge of 687. The ends 29a of strands 29 which continue to encircle members 630 as they pass over sheaves 638 may be removed from members 630 by strippers 39. The completed sheet material 8, which may have the appearance shown in FIGURE 38 prior to being severed from members 630, may pass over idler roll 698 and be wound up on wind-up roll 699. It may be subjected to one or more finishing treatments as hereinbefore described prior to being wound up on roll 699.

Referring now to FIGURE 43 there is shown an enlarged cross section of table 631 which may be interposed between parallel portions of endless flexible members 630 and may be provided with means to vary its effective width which may comprise channel-like members 901 which may extend along edges of table 631 and may be adapted to be seated in grooves 632. The cross-sectional form of members 901 may be substantially that of a crescent. Members 901 may be spaced apart from grooves 632 in the edges of table 631, in order to widen the effective width of tables 631, by means of tubes 902 attached to members 901 and screws 903. Tubes 902 may be slidably inserted in holes 904 in the edges of table 631 and the inside bores of said tubes may be threaded. Screws 903 may be externally threaded to fit the internal threads in tubes 902 and members 901 may be provided with holes 905 concentric with the bores of tubes in 902 to permit a screwdriver or "Allen" wrench to be inserted therethrough. Screws 903 may bear against the bottoms of holes 904 and may be rotated by means of screwdriver or wrench such as an "Allen" wrench inserted in sockets 906 in the outermost ends thereof.

If the threads of tubes 902 and screws 903 are right-handed, clockwise turning of screws 903 may cause members 901 to be extended and supported further from edge grooves 632 in table 631 whereas counter-clockwise turning of screws 903 may cause members 901 to be supported less outwardly from grooves 632 or to be seated in grooves 632. Thus the distance between members 630 may be

varied to whatever degree may be found suitable in operation, that is, the effective width of table 631 may be varied.

Modifications of the invention which are equivalent in scope and function to the invention as hereinabove described will be apparent to those skilled in the art and it is the intent of the inventor that the invention includes such modifications.

Thus it may be seen that the invention is broad in scope and is not to be limited excepting by the claims.

Having thus disclosed my invention, I claim:

1. In a device for producing a sheet of material comprising polymeric resin having imbedded therein two planar layers of continuous filament strands of yarn, wherein said strands in each of said layers are at least substantially parallel to one another and have their axes in the same plane and have their axes crossing in the two planar layers and extend substantially from one edge of said sheet to the opposite edge of said sheet, each of said planes being substantially parallel to the two major surfaces of said sheet; a pair of endless movable flexible members, means for maintaining said flexible members in parallel spaced relationship for a portion of their length, means for driving said members longitudinally through said portion at the same rate as each other, means for winding weft strand around said portion whereby two layers of weft strands are formed, means for combining said two layers into a single layer of weft strands, said endless flexible members extending alongside and beyond said combining means, means for providing a layer of warp strands adjacent to said single layer of weft strands in said portion, means for impregnating said warp and weft layers with polymerizable material, and means for applying heat to said impregnated layers to polymerize said polymerizable material in said portion while maintaining said strands under tension, said endless flexible members extending past said impregnating means and said means for applying heat, characterized by said combining means comprising at least one roll.

2. The device of claim 1 wherein said means for winding comprises a platform rotatable in a horizontal plane around a vertical axis and at least one warp beam mounted on said platform.

3. The device of claim 1, further characterized by means for passing a sheet of thermoplastic material between said layers of weft strands, said sheet traveling in a direction parallel to said parallel portions of said members and at the same rate thereas.

4. The device of claim 1, further characterized by means for passing a sheet of material of approximately the width of said layer of warp strands between said roll and said strands and by means for adhering said strands to said sheet.

5. In a device for producing a sheet of material comprising polymeric resin having imbedded therein two planar layers of continuous filament strands of yarn, wherein said strands in each of said layers are at least substantially parallel to one another and have their axes in the same plane and have crossing axes in the two planar layers and extend substantially from one edge of said sheet to the opposite edge of said sheet, each of said planes being substantially parallel to the two major surfaces of said sheet; a pair of endless movable flexible members, means for maintaining said flexible members in parallel spaced relationship for a portion of their length, means for driving said members longitudinally at the same rate as each other through said portion, means for winding weft strand around said portion whereby two layers of weft strands are formed, means for providing at least one layer of warp strands adjacent to said layers of weft strands, means for combining said warp strands with said adjacent weft strands in closely contacting relation, said endless flexible member extending alongside and beyond said combining means, means for applying heat to said impregnated layers to polymerize said polymerizable material in said portion while maintaining said strands under

tension, said endless flexible members extending past said impregnating means and said means for applying heat.

6. The device of claim 5 further characterized by means for winding a plurality of strands around said movable members while causing said members to move forward at a constant rate.

7. The device of claim 5 wherein said means for winding comprises a platform rotatable in a horizontal plane around a vertical axis and at least one warp beam mounted on said platform.

8. The device of claim 5 further characterized by means for passing a sheet of thermoplastic material between said layers of weft strands, said sheet traveling in a direction parallel to said parallel portion of said members and at the same rate thereas.

9. The device of claim 5 further characterized by means for passing a sheet of material of approximately the width of said layer of warped strands over said roll adjacent said strands and by means for adhering said strands to said sheet.

10. In a device for producing a sheet of material comprising polymeric resin having imbedded therein two planar layers of continuous filament strands of yarn, wherein said strands in each of said layers are at least substantially parallel to one another and have their axes in the same plane and have crossing axes in the two planar layers and extend substantially from one edge of said sheet to the opposite edge of said sheet, each of said planes being substantially parallel to the two major surfaces of said sheet; a pair of endless movable flexible members, means for maintaining said flexible members in parallel spaced relationship for a portion of their length, means for driving said members longitudinally at the same rate as each other in said portion, means for winding weft strand around said portion whereby two layers of weft strands are formed at an angle to each other, means for combining said two layers into closely contacting relation, said endless flexible members extending alongside and beyond said combining members, means for impregnating said weft layers with polymerizable material, and means for applying heat to said impregnated layers to polymerize said polymerizable material while maintaining said strands under tension in said portion, said endless flexible members extending past said impregnating means and said means for applying heat.

11. The device of claim 10 further characterized by means for winding a plurality of strands around said movable members while causing said members to move forward at a constant rate.

12. The device of claim 10 wherein said means for winding comprises a platform rotatable in a horizontal plane around a vertical axis and at least one warp beam mounted on said platform.

13. The device of claim 10 further characterized by means for causing a sheet of thermoplastic material to pass between said layers of weft strands, said sheet traveling in a direction parallel to said parallel portion of said members and at the same rate thereas.

14. The device of claim 10, further characterized by means for passing a sheet of material of approximately the length of said weft strands over said roll adjacent said strands and by means for adhering said strands to said sheet.

15. In a device for producing a sheet of material comprising polymeric resin having imbedded therein two planar layers of continuous filament strands of yarn, wherein said strands in each of said layers are at least substantially parallel to one another and have their axes in the same plane and have crossing axes in the two planar layers and extend substantially from one edge of said sheet to the opposite edge of said sheet, each of said planes being substantially parallel to the two major surfaces of said sheet; means for disposing strands in said planar layers, means for impregnating said strands with polymerizable material and means for curing said mate-

rial, said means for disposing said strands in said planar layers comprising a pair of endless movable flexible members extending past said impregnating means and winder means, means interposed between said members for maintaining said members spaced apart in substantially parallel relationship for a portion of their lengths, means for continuously carrying at least one spool of strand repeatedly around that portion of said members so spaced, to thereby form a layer of parallel strands above said interposed means and a layer of parallel strands below said interposed means, and means for carrying said members past said interposed means while simultaneously maintaining them in said spaced relationship.

16. In a device for producing a sheet of material comprising polymeric resin having imbedded therein two planar layers of continuous filament strands of yarn, wherein said strands in each of said layers are at least substantially parallel to one another and have their axes in the same plane and have crossing axes in the two planar layers and extend substantially from one edge of said sheet to the opposite edge of said sheet, each of said planes being substantially parallel to the two major surfaces of said sheet; a pair of endless movable flexible members, means interposed between portions thereof adapted to maintain said portions in parallel spaced relationship, and adapted to support said flexible members and to allow each of said members to pass endlessly adjacent said interposed means laminating elements, means for driving said members toward and past said laminating elements at the same rate as each other, means for winding at least one weft strand repeatedly around said members and said interposed means, means for providing at least one layer of warp strands and introducing said warp strands between said laminating elements whereby said laminating elements may compress said planar layers together, means for impregnating said warp and weft layers with polymerizable material, and means for applying heat to said impregnated layers to polymerize said polymerizable material, while maintaining said strands under tension in said portions, said endless flexible members extending past said impregnating means and said means for applying heat.

17. The device of claim 16 further characterized by means for winding only a single strand around said movable members, while moving said members forward at a constant rate.

18. In a device for producing a sheet of material comprising polymeric resin having imbedded therein two planar layers of continuous filament strands of yarn, wherein said strands in each of said layers are at least substantially parallel to one another and have their axes in the same plane and having crossing axes in the two planar layers and extend substantially from one edge of said sheet to the opposite edge of said sheet, each of said planes being substantially parallel to the two major surfaces of said sheet; two laminating elements comprising parallel rolls, a table, adjustable in width having one end supported by a roll adjustable in height, said end being adjacent said laminating elements, having the other end hingedly supported in rigidly supported journals, grooves in the edges of said table, cables adapted to seat in and slide in said grooves and to extend alongside said laminating elements, means for providing a layer of weft strands above said table and a layer of weft strands below said table including means for winding at least one strand repeatedly around said cables and said table, said cables adapted for introducing said layers into said parallel rolls as a single layer, means for impregnating said weft strands, means for introducing a warp impregnated with polymerizable material into said laminating elements, means including said cables adapted to provide crosswise tension in said weft strands, grooves in said laminating elements adapted to maintain said cables spaced apart and to maintain tension in said weft strands, and means

for applying heat and pressure to the assembly of said impregnated weft and warp layers.

19. The device of claim 18 provided with means for winding only a single strand around said cables while causing said cables to move forward at a constant rate.

20. The method of producing a sheet of material comprising polymeric resin having imbedded therein two planar layers of continuous filament strands of yarn wherein said strands in each of said layers are at least substantially parallel to one another and have their axes in the same plane and have crossing axes in the two planar layers, and extend substantially from one edge of said sheet to the opposite edge of said sheet, each of said planes being substantially parallel to the two major surfaces of said sheet; which comprises making said sheet while maintaining substantially all said strands in both of said layers under tension by disposing strands in said planar layers, imposing tension on substantially all of said strands, impregnating said strands with polymerizable material and curing said material while maintaining said tension, wherein said tension is imposed and maintained in the strands in one of said layers by causing them to be passed around longitudinally extended flexible members and by exerting an outwardly directed restraining force on said members.

21. A method of producing a sheet of material comprising polymeric resin having imbedded therein two planar layers of continuous filament strands of yarn wherein said strands in each of said layers are at least substantially parallel to one another and have their axes in the same plane and have crossing axes in the two planar layers and extend substantially from one edge of said sheet to the opposite edge of said sheet, each of said planes being substantially parallel to the two major surfaces of said sheet; which comprises continuously making said sheet while continuously maintaining substantially all of said strands in both of said layers under tension by continuously disposing strands in said planar layers, continuously advancing said strands and imposing tension thereon, continuously impregnating said strands with polymerizable material and curing said material while maintaining said tension, wherein said tension is imposed and maintained in strands disposed at an angle to the direction of said advance by passing them continuously around longitudinally extended flexible members and by then exerting an outwardly restraining force on said members.

22. A method of producing a sheet of material comprising polymeric resin having imbedded therein two planar layers of continuous filament strands of yarn wherein said strands in each of said layers are at least substantially parallel to one another and have crossing axes in the two planar layers and have their axes in the same plane and extend substantially from one edge of said sheet to the opposite edge of said sheet, each of said planes being substantially parallel to the two major surfaces of said sheet; which comprises continuously making said sheet while continuously maintaining substantially all of said strands in both of said layers under tension by continuously disposing strands in planar layers, continuously advancing said strands and imposing tension thereon, continuously impregnating said strands with polymerizable material and curing said material while maintaining said tension wherein said tension is imposed and maintained in strands disposed at an angle to the direction of said advance by passing them continuously around longitudinally extended flexible members and by then exerting an outwardly directed restraining force on said members prior to impregnating said strands disposed at an angle to the direction of advance.

23. The method of producing a sheet of material comprising polymeric resin having imbedded therein two planar layers of continuous filament strands of yarn comprising continuously disposing a plurality of strands into two layers wherein said strands in each of said layers are at least substantially parallel to one another and have their axes in the same plane and have crossing axes in the

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two planar layers and extend substantially from one edge of said sheet to the opposite edge of said sheet, each of said planes being substantially parallel to the two major surfaces of said sheet, continuously advancing said strands, continuously imposing tension on all of the strands in each of said layers, the tension in those strands which are disposed at an angle to the direction of said advance being imposed by passing such strands around a pair of longitudinally extending and continuously advancing flexible members and exerting an outward restraining force on said strands; then, while maintaining said tension, impregnating said strands with polymerizable material; then curing said material; then relaxing said tension.

24. The process of making material comprising continuous filament strands of yarn secured together with synthetic resin, which comprises providing a substantially planar layer of substantially parallel tensioned strands and providing substantially parallel thereto a plurality of like layers with the strands in each of the layers having an angular relationship to those in each adjacent layer, said strands having crossing axes in the two planar layers, maintaining longitudinal tension on all said strands while applying polymerizable material to at least one of said layers and bringing said layers into contact with one another, and polymerizing said polymerizable material while maintaining tension in said strands and while maintaining said relationship between said strands.

25. The process of making material comprising continuous filament strands of yarn secured together with synthetic resin, which comprises winding at least one strand under longitudinal tension around a substantially parallel spaced portion of a pair of moving endless flexible members maintaining a spaced relation between opposite portions of said yarn so wound thus providing two substantially planar substantially parallel layers of substantially parallel longitudinal tensioned strands of yarn and then causing said strands to pass between laminating elements while remaining attached to said members and

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while maintaining said strands under longitudinal tension.

26. The process of making material comprising continuous filament strands of yarn secured together with synthetic resin, which comprises providing at least two substantially planar substantially parallel layers of substantially parallel longitudinally tensioned strands of yarn having solidifiable organic polymeric material at the points of adjacency of said strands and having an angular relationship between strands in adjacent layers, said strands having crossing axes in the two planar layers and then solidifying said solidifiable material while maintaining longitudinal tension in said strands and while maintaining said relationship between said strands.

27. The process of making material comprising continuous filament strands of yarn secured together with synthetic resin, which comprises providing a substantially planar layer of substantially parallel longitudinally tensioned strands and providing substantially parallel thereto a plurality of like layers with the strands in each of the layers having an angular relationship to those in each adjacent layer, said strands having crossing axes in the two planar layers, applying solidifiable organic polymeric material to at least one of said layers bringing said layers into contact with one another and solidifying said solidifiable material while maintaining longitudinal tension in said strands and while maintaining said relationship between said strands.

References Cited in the file of this patent

UNITED STATES PATENTS

1,195,949	Carney	Aug. 22, 1916
2,725,323	Chadwick et al.	Nov. 29, 1955
2,772,993	Magnuson	Dec. 4, 1956
2,797,728	Slyter et al.	July 2, 1957

FOREIGN PATENTS

522,525	Canada	Mar. 13, 1956
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