

[54] CIRCULAR WEAVING APPARATUS  
PRODUCT AND PROCESS

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2,998,030 8/1961 Koppelman et al. ....139/191

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[57] ABSTRACT

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

[22] Filed: Dec. 8, 1969

[21] Appl. No.: 882,387

Related U.S. Application Data

[62] Division of Ser. No. 793,921, Dec. 31, 1968.

[52] U.S. Cl. ....139/13

[51] Int. Cl. ....D03d 37/00

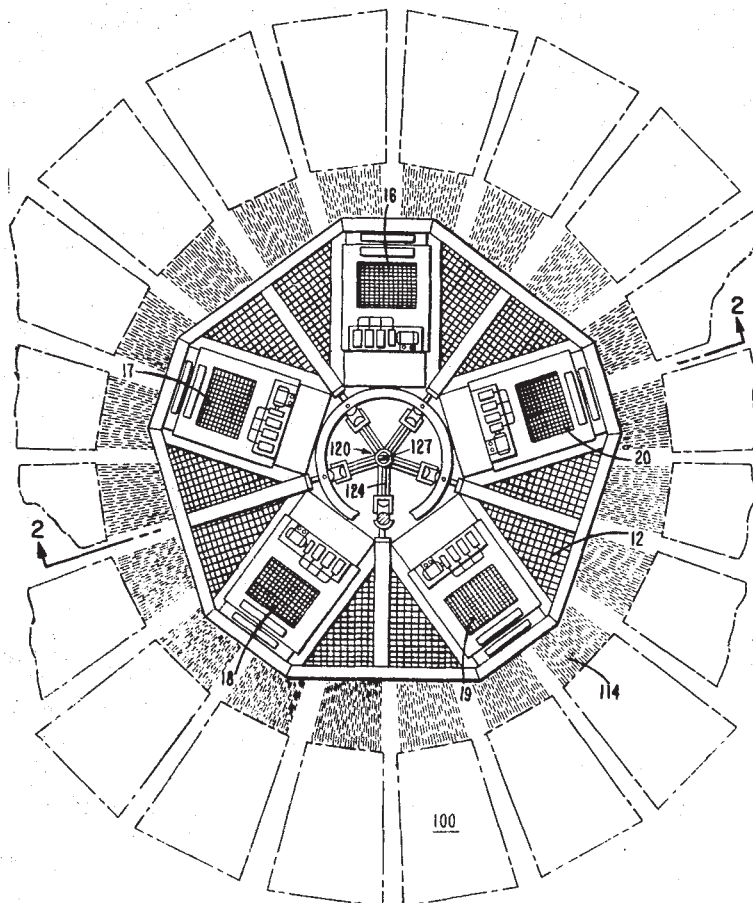
[58] Field of Search.....139/12, 13, 1, 16, 191

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69 Claims, 77 Drawing Figures



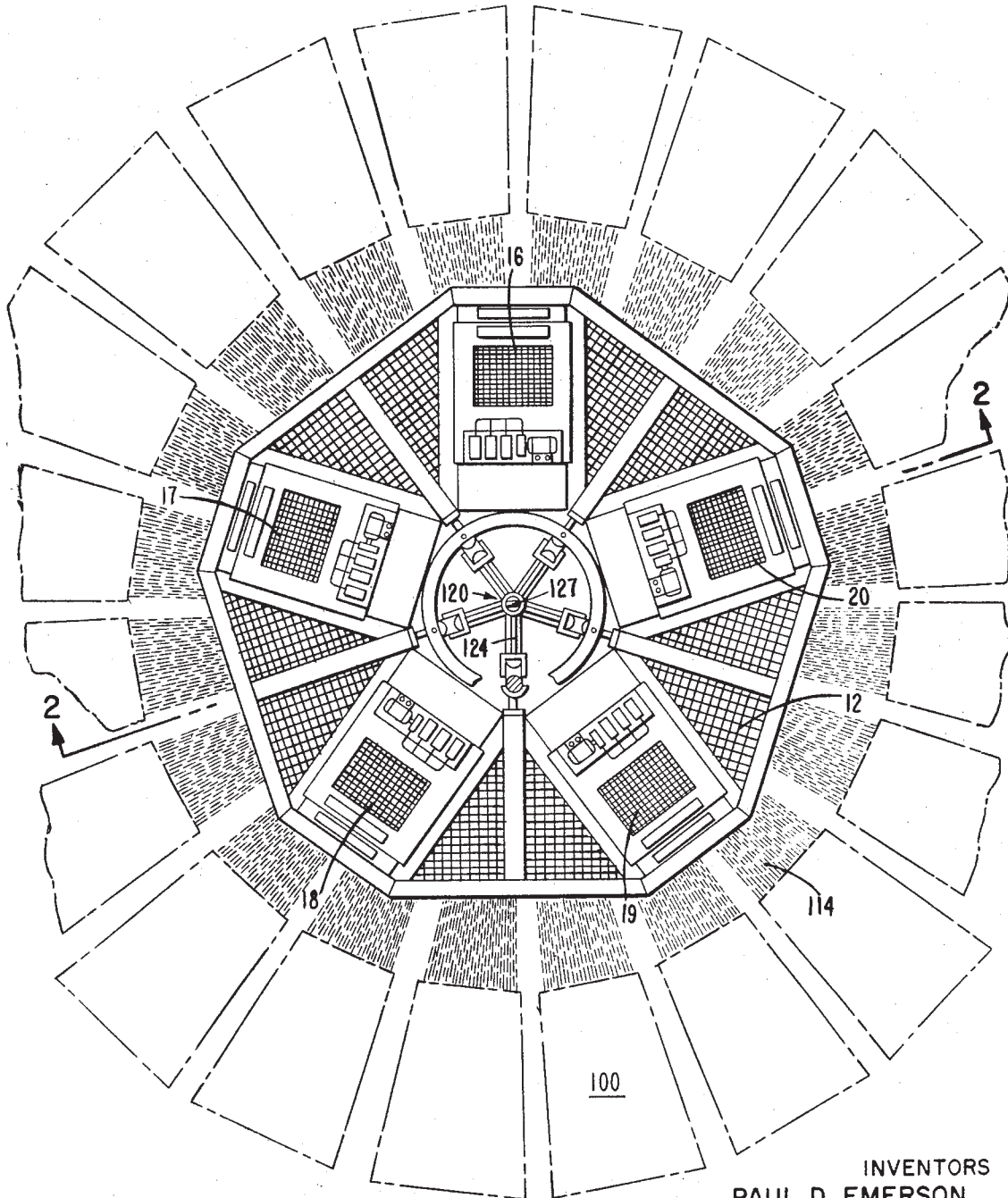


FIG. 1

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ATTY.



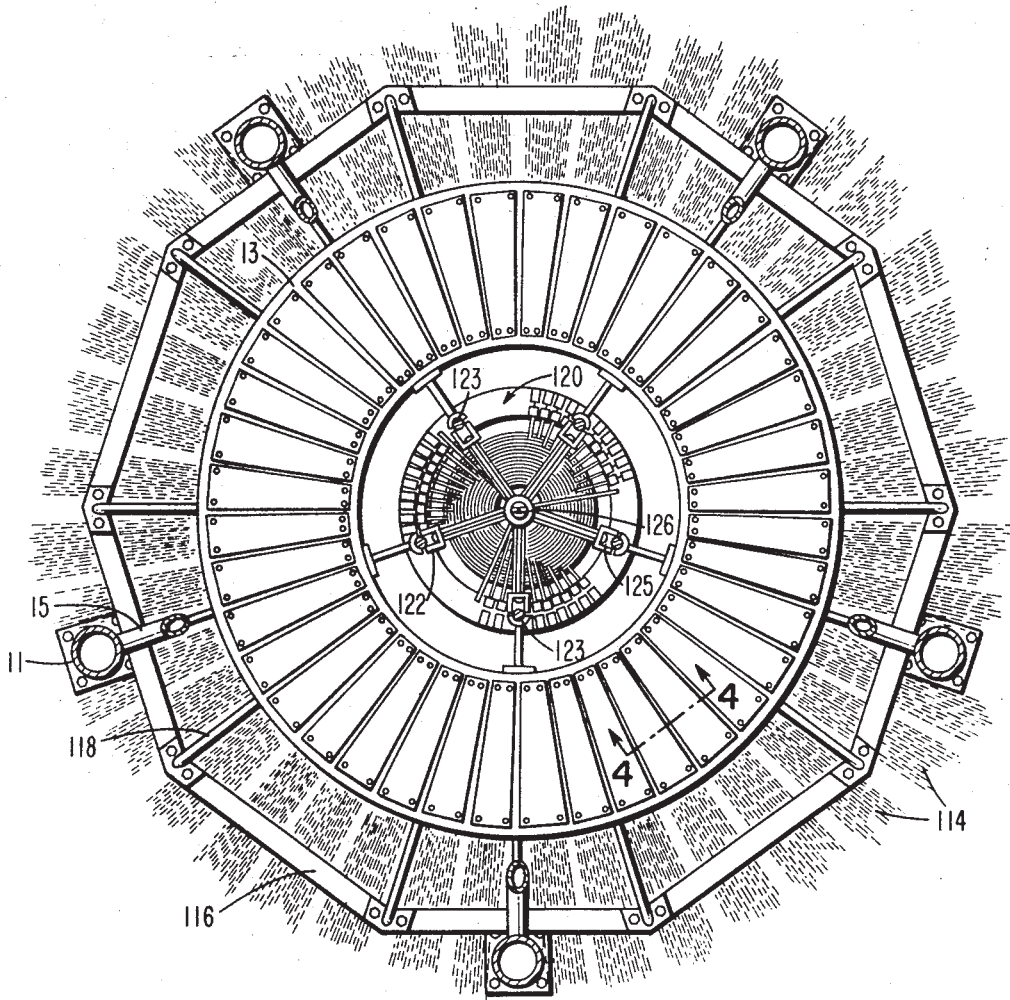


FIG. 3

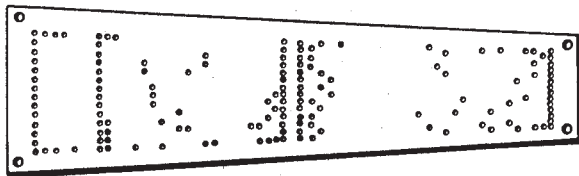


FIG. 5



FIG. 4

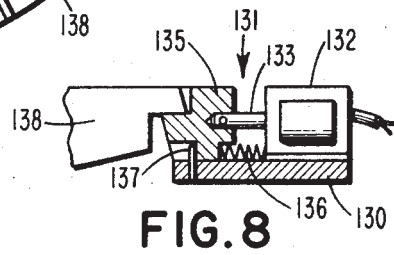
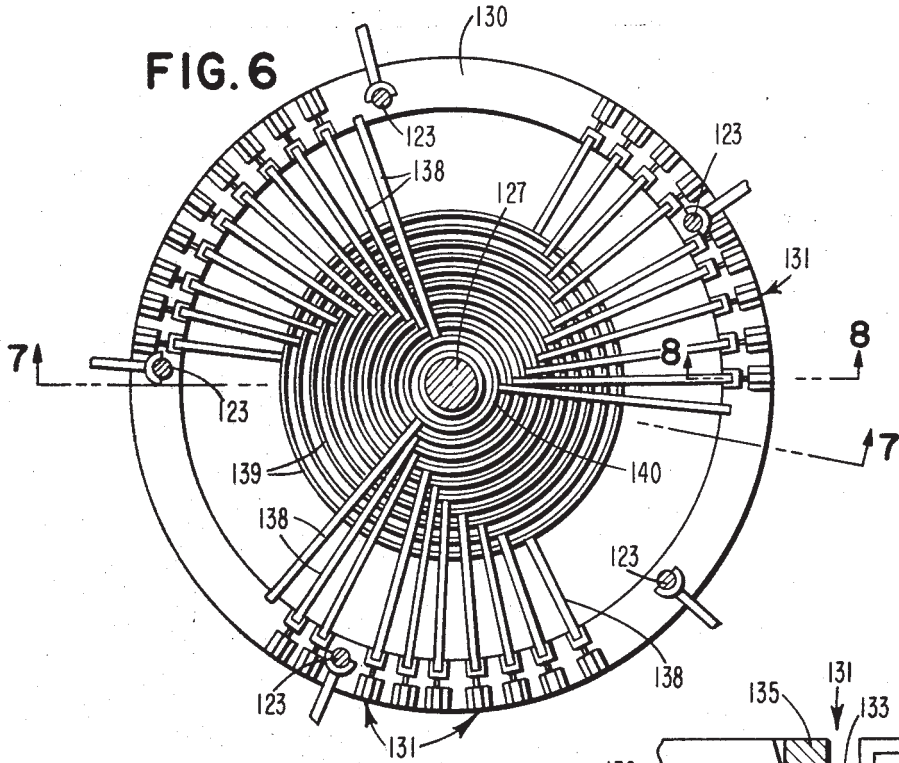


FIG. 8

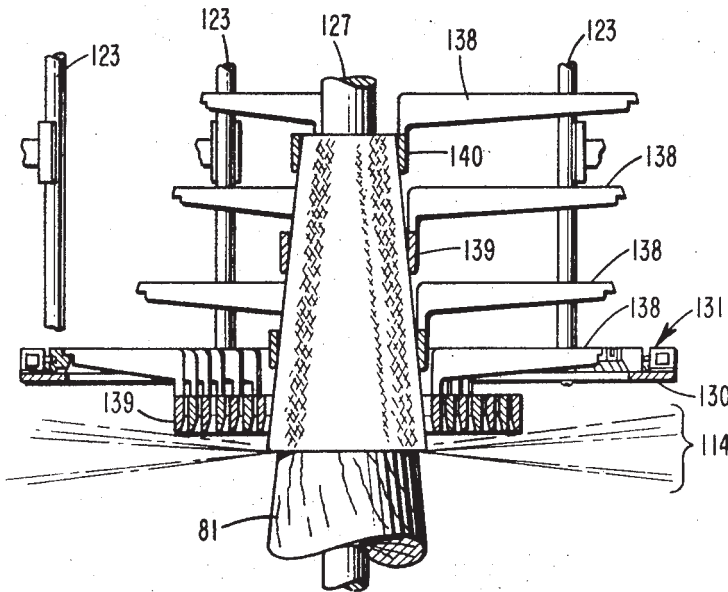


FIG. 7

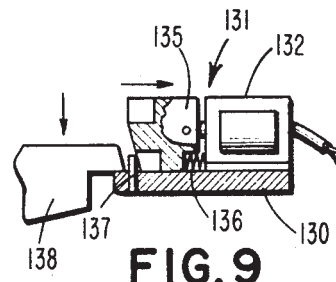
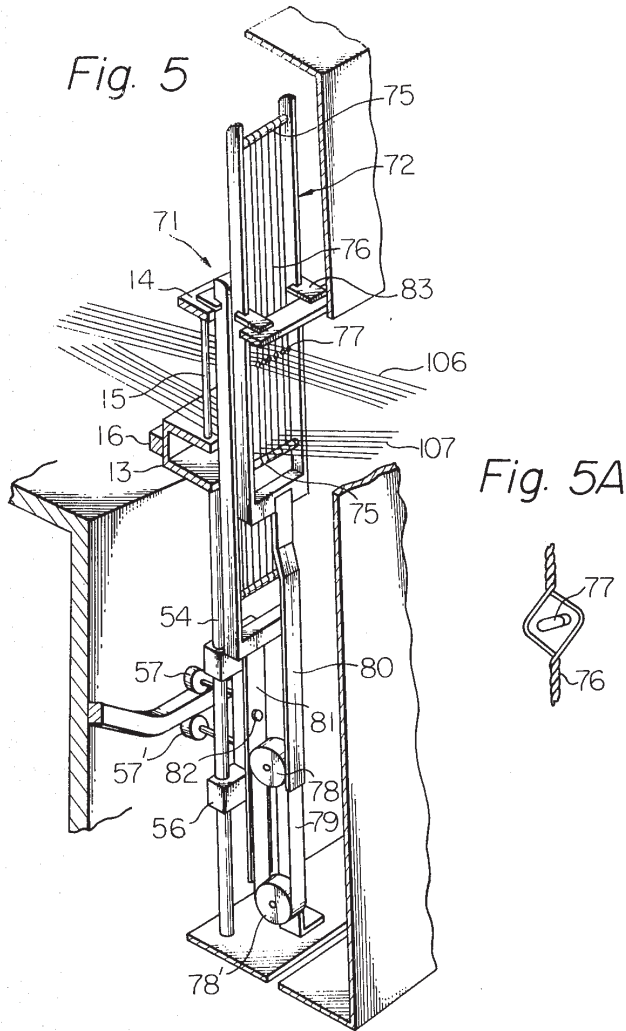


FIG. 9





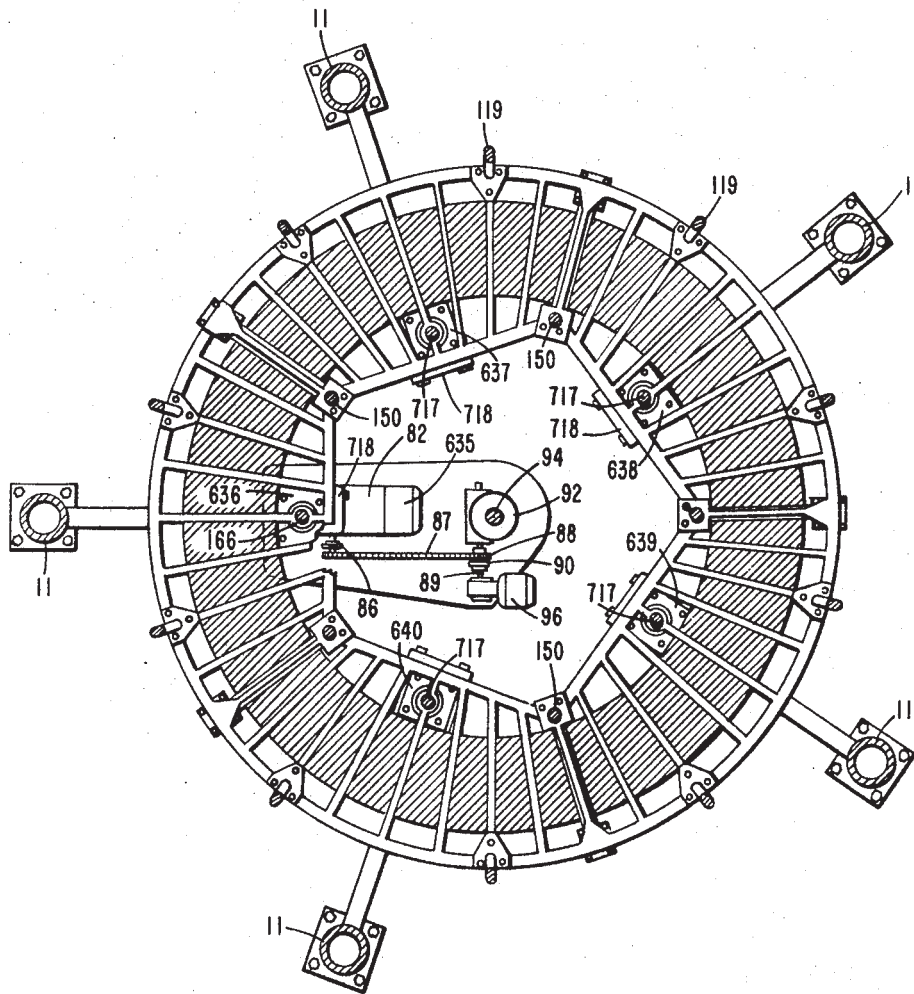


FIG. 11

FIG. 12

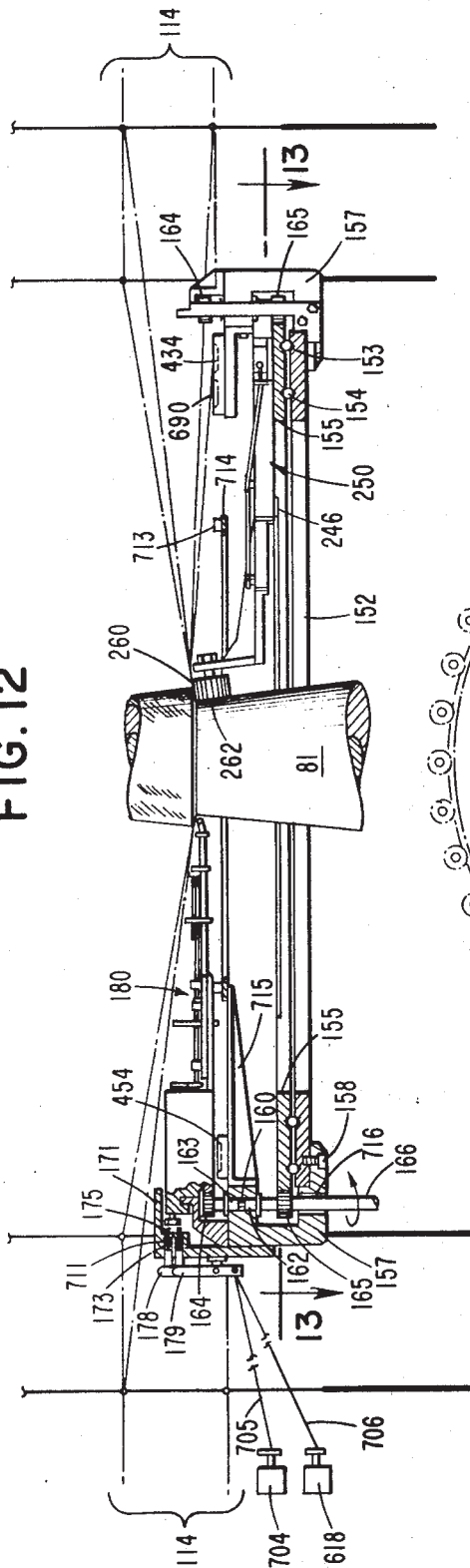
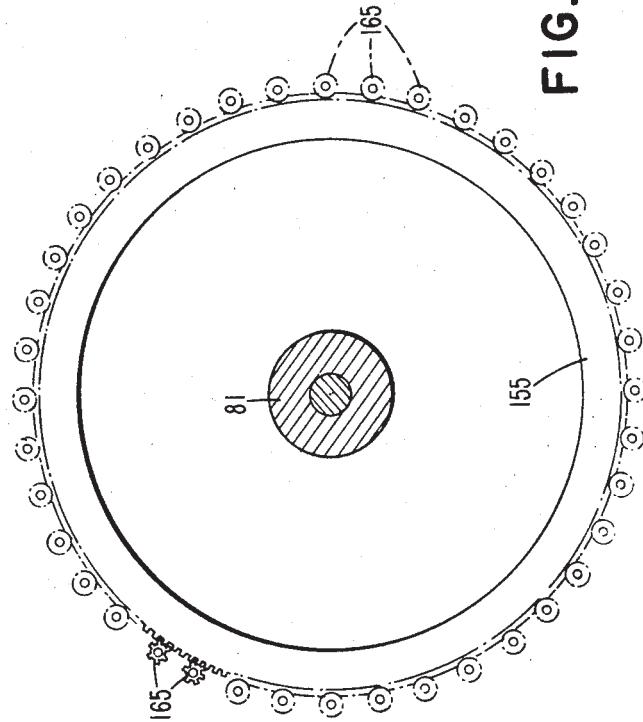
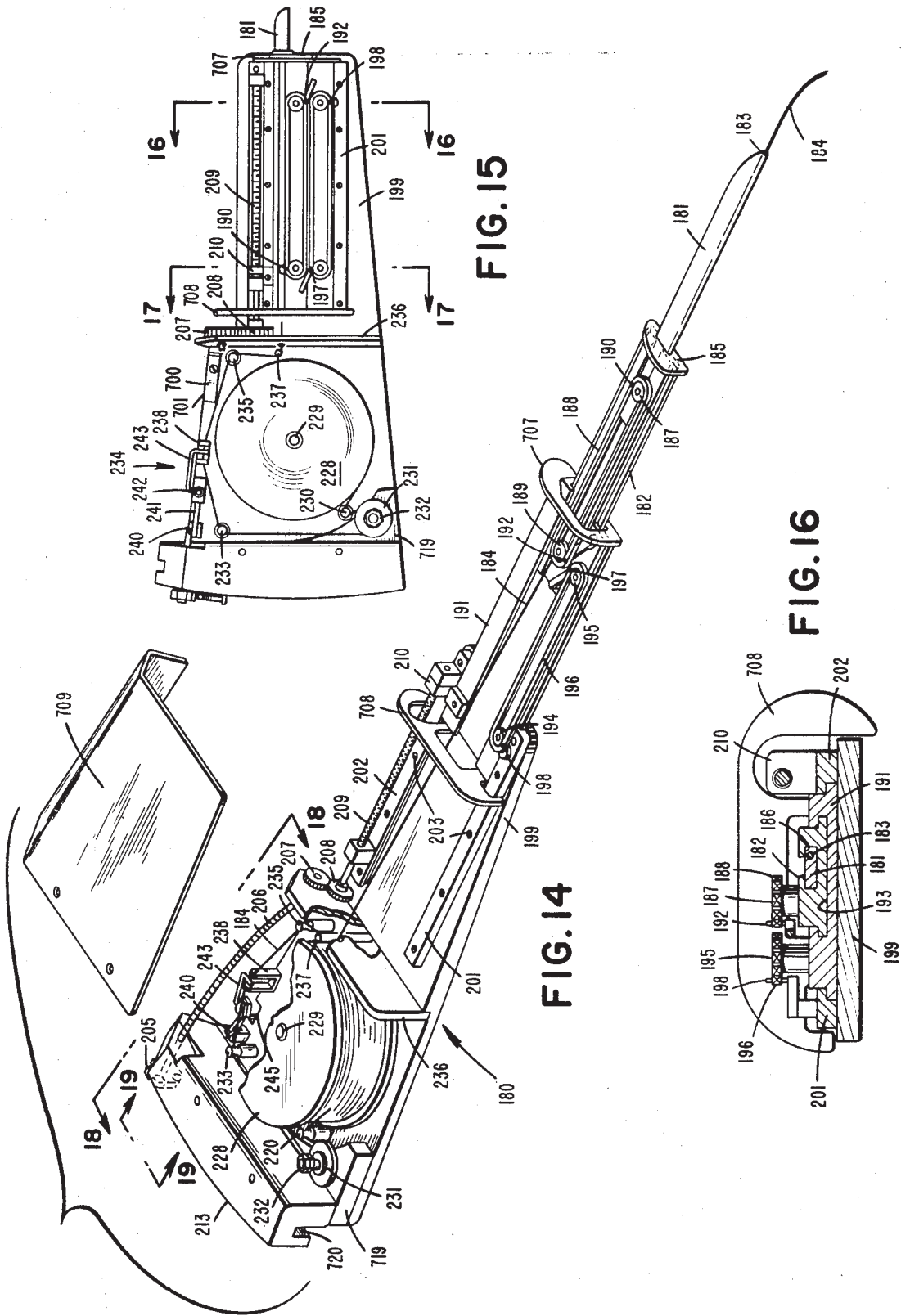


FIG. 13







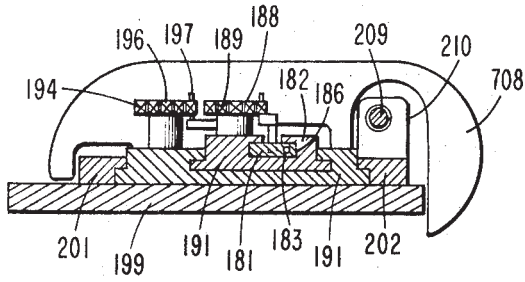


FIG. 17

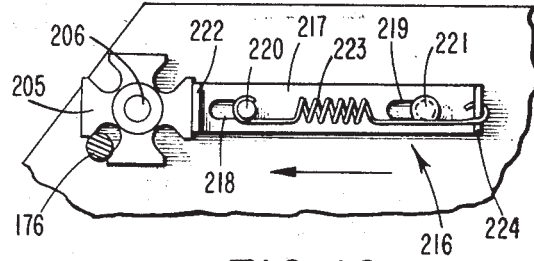


FIG. 19

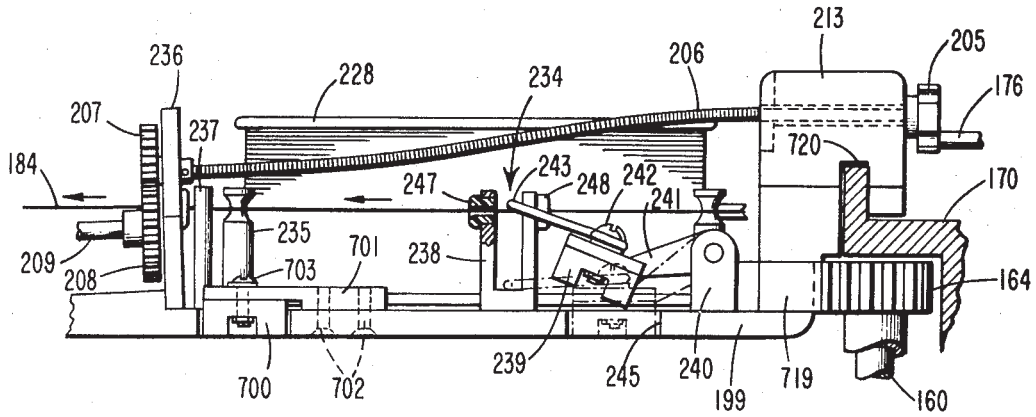


FIG. 18

FIG. 23

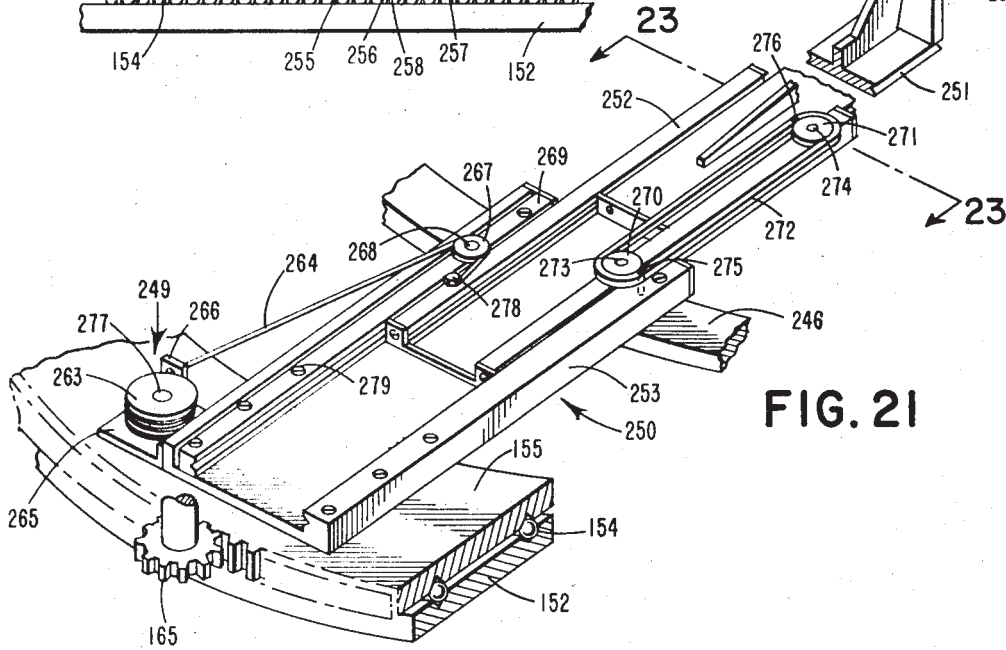
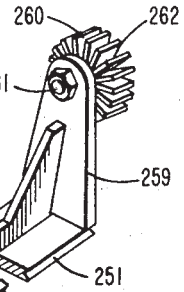
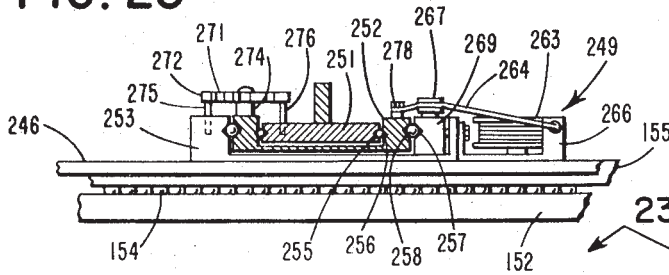


FIG. 21

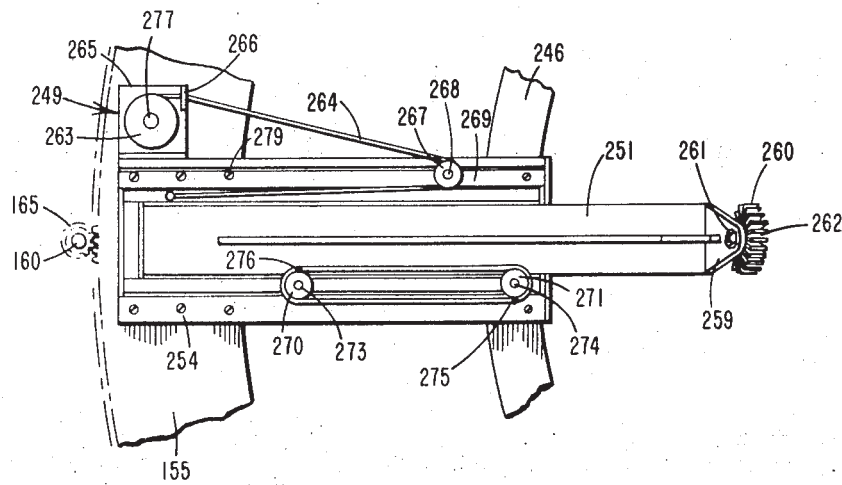


FIG. 22

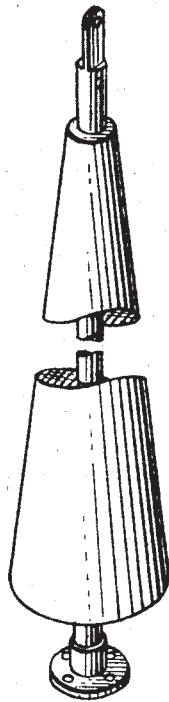


FIG. 24

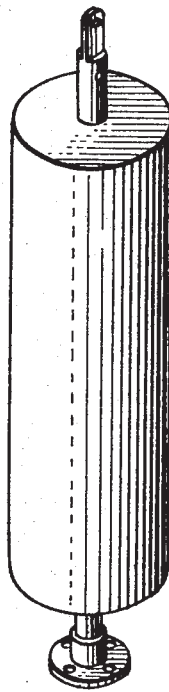


FIG. 25

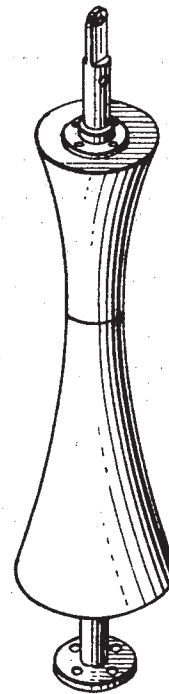


FIG. 26



FIG. 27

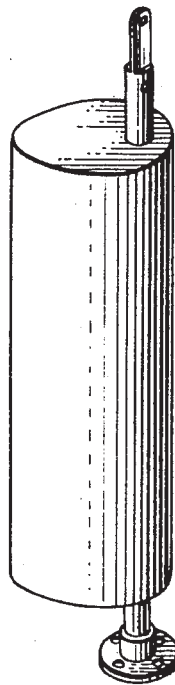


FIG. 28

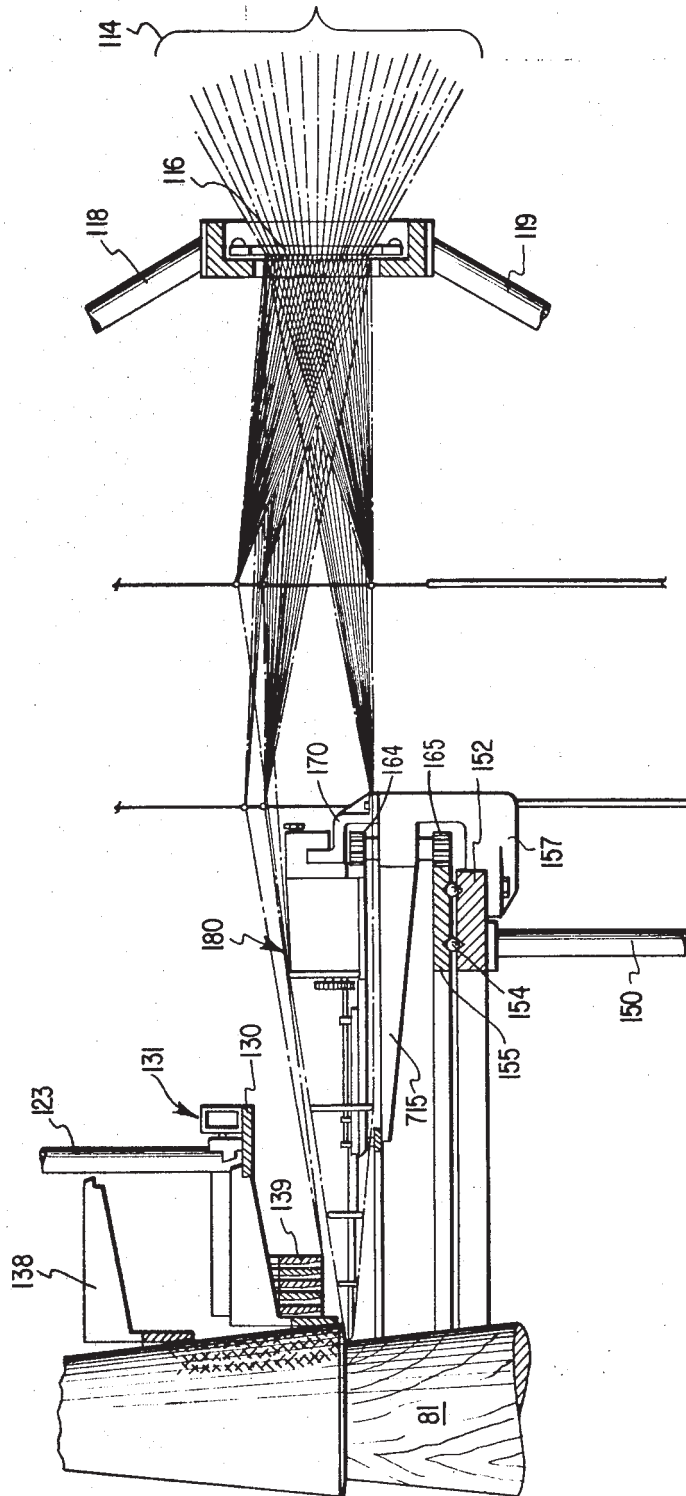


FIG. 29

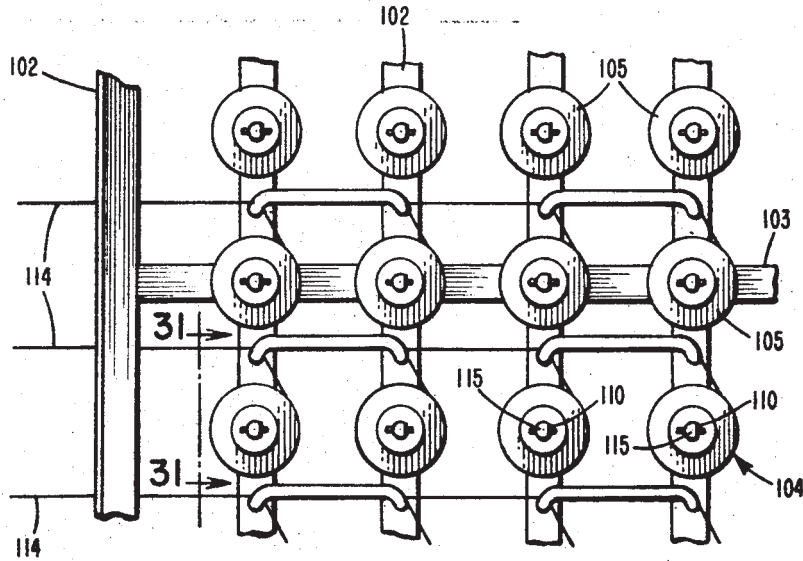


FIG. 30

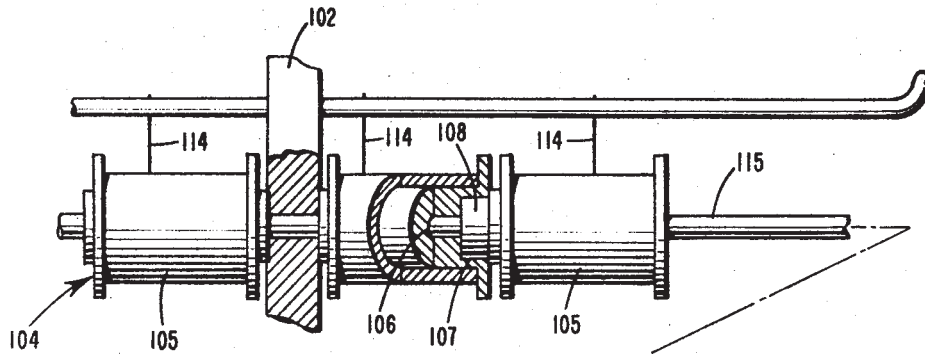


FIG. 31

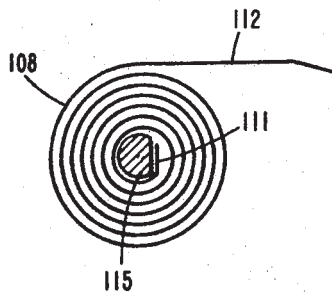
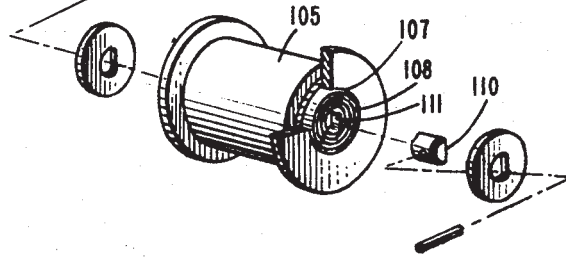


FIG. 32





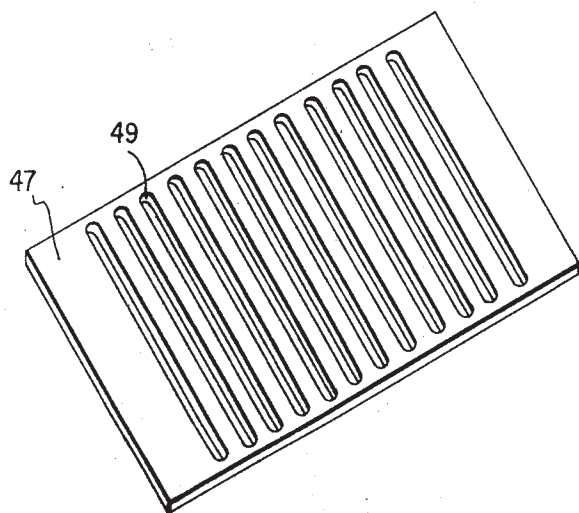
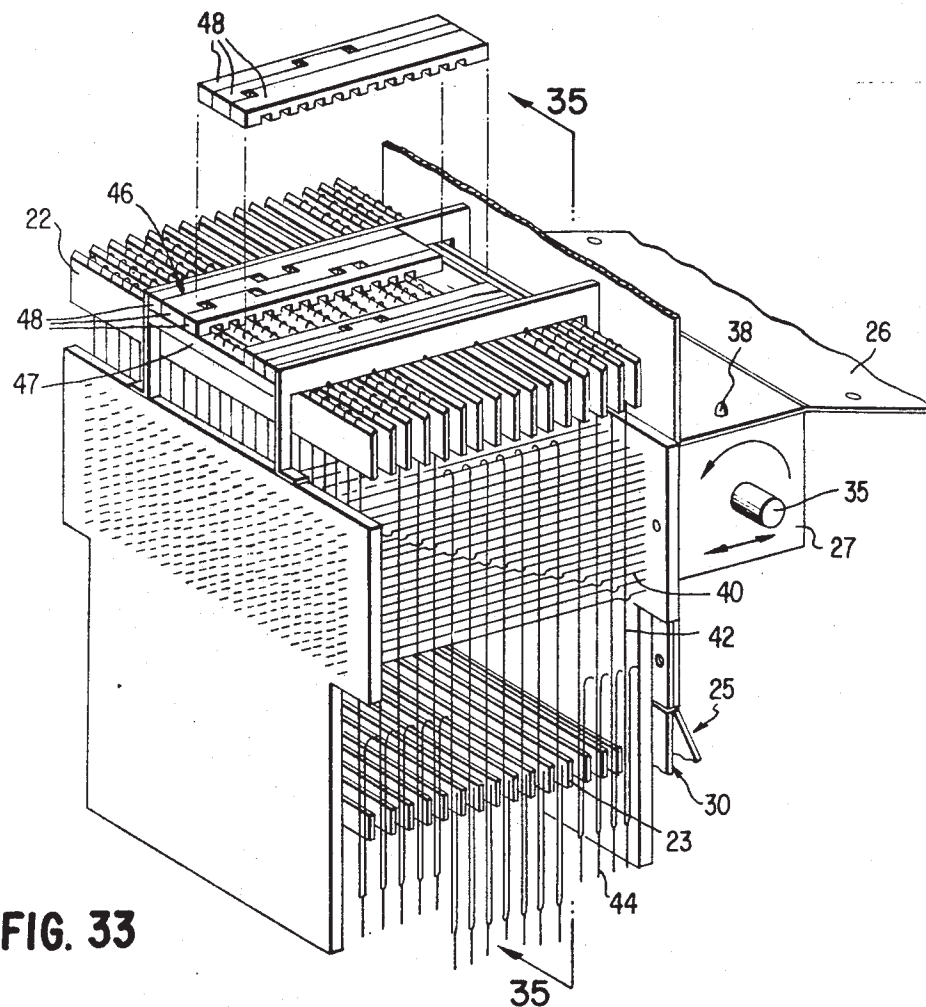


FIG. 35

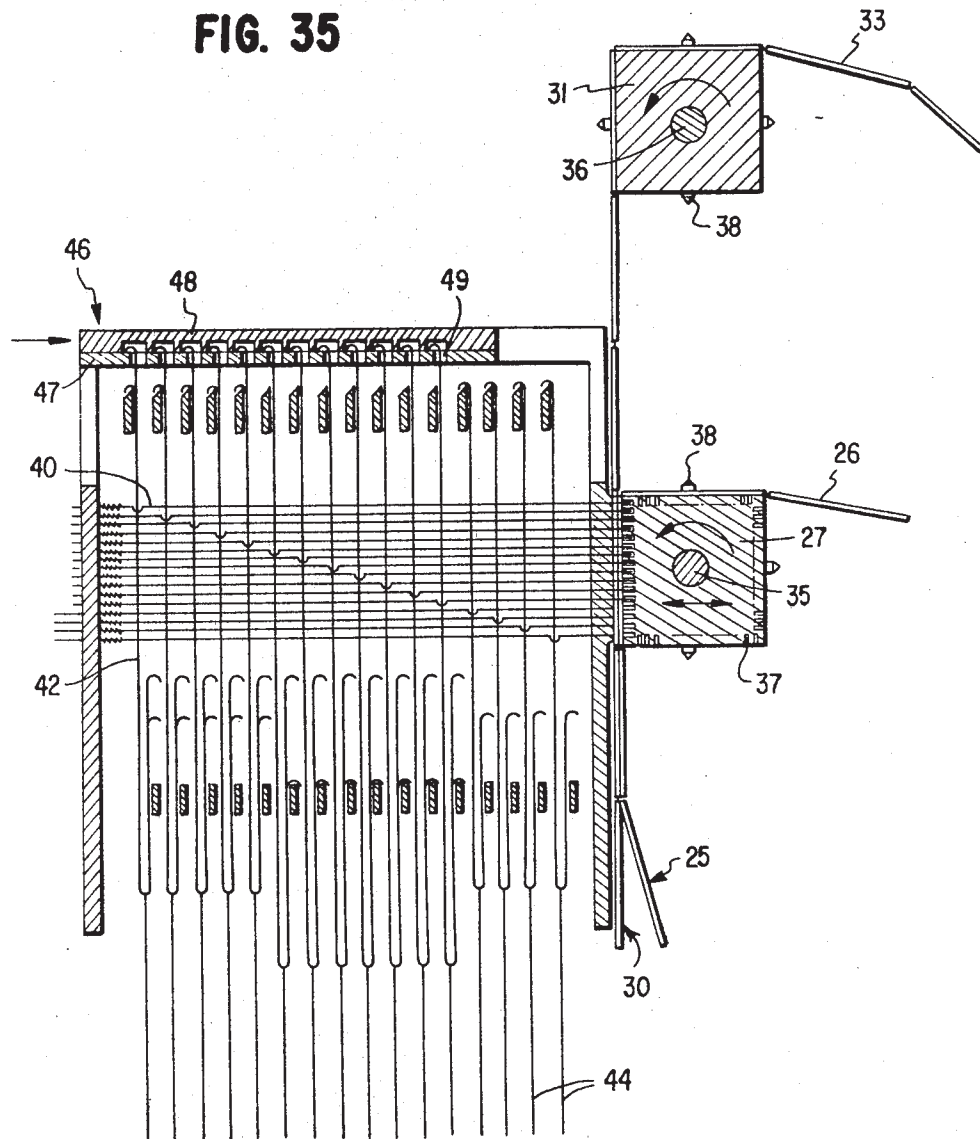
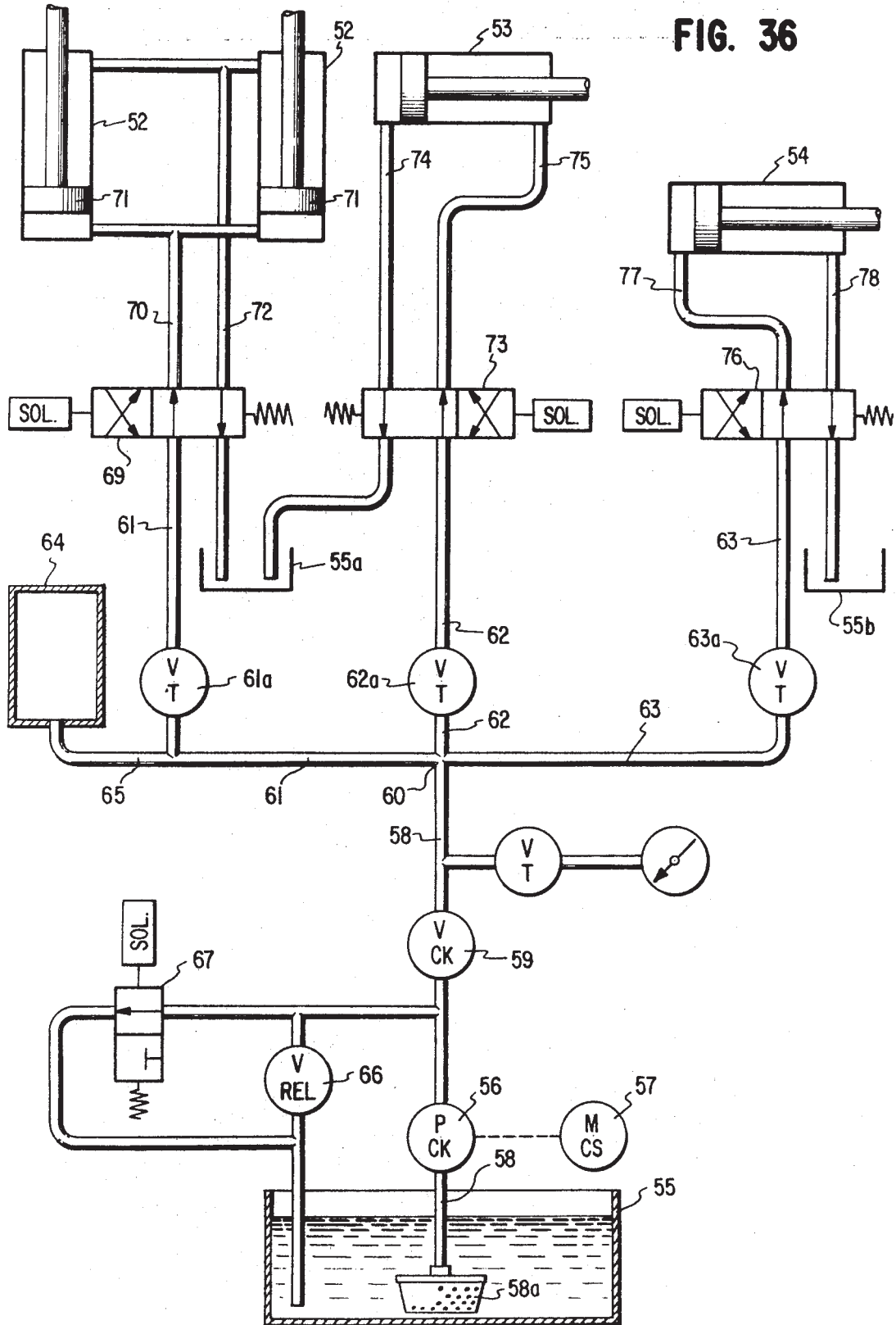


FIG. 36



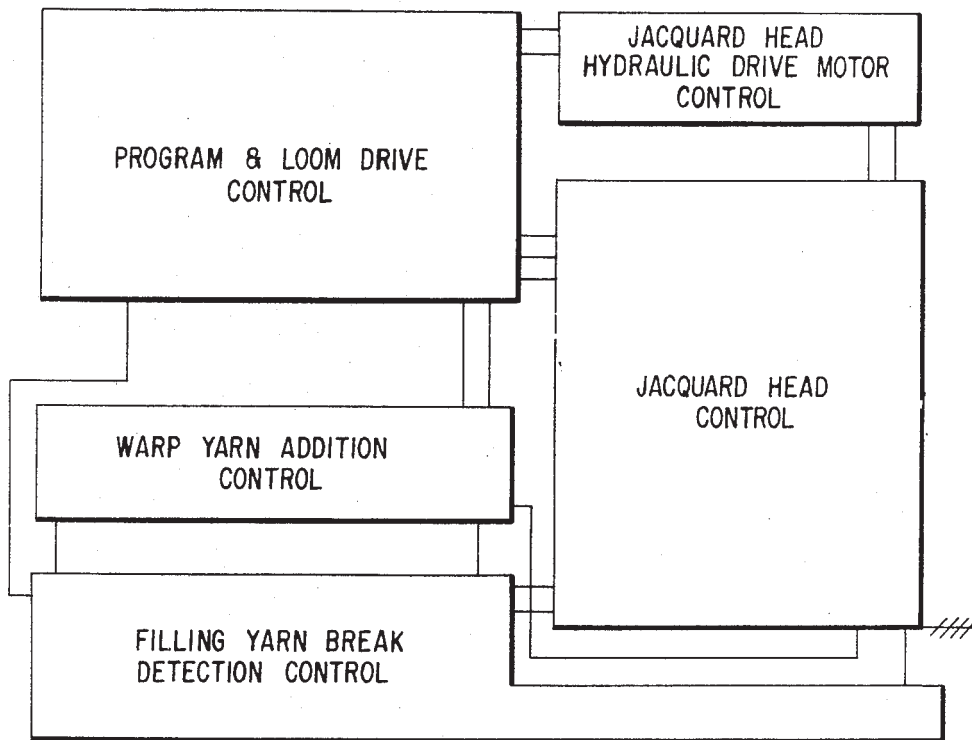


FIG. 37

FIG. 39

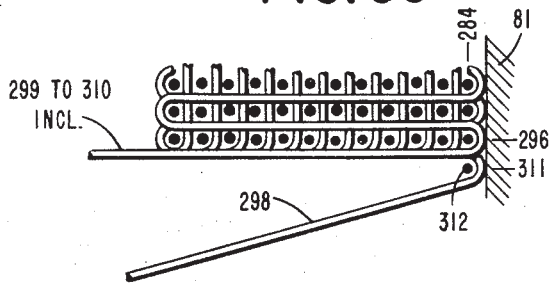


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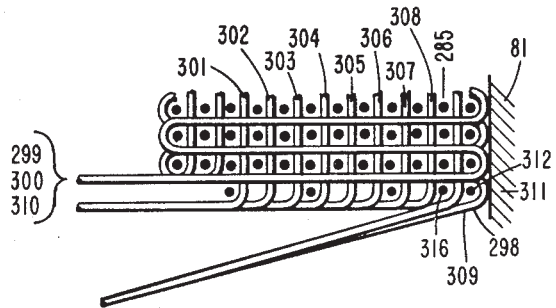


FIG. 40

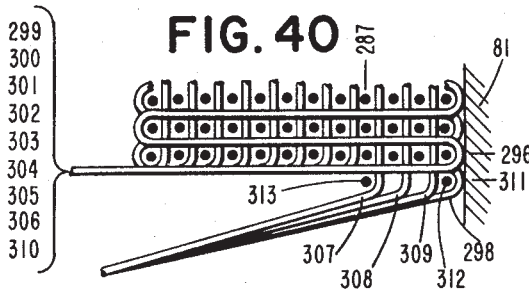


FIG. 44

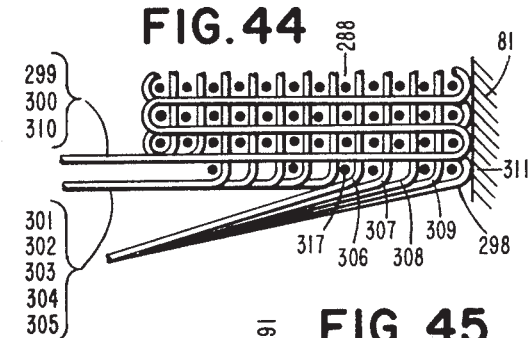


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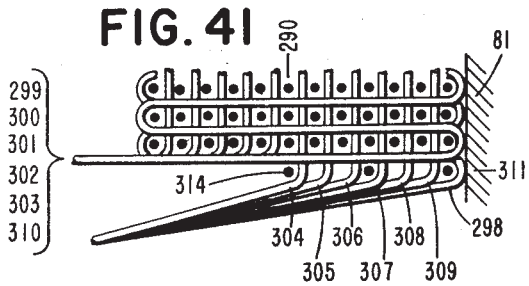


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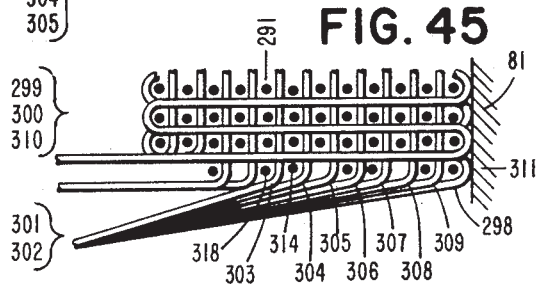


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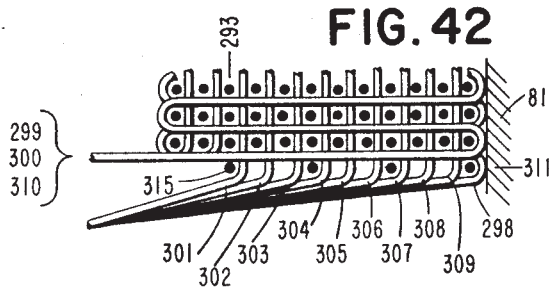


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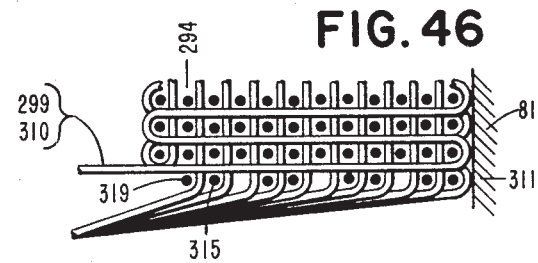
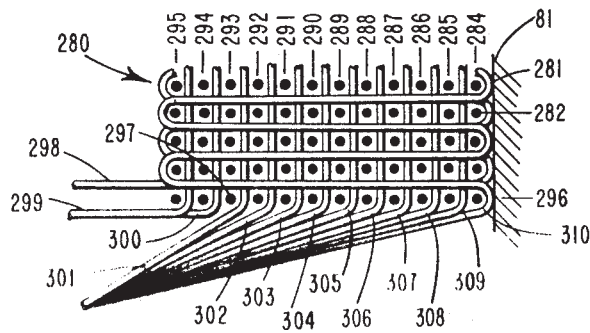
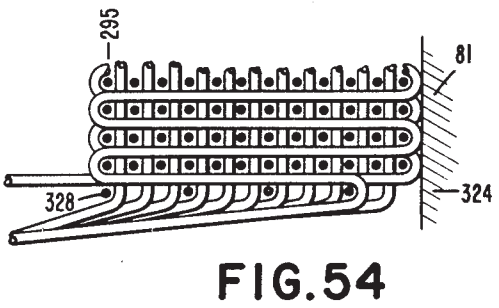
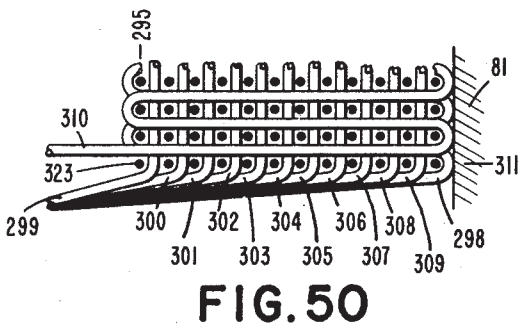
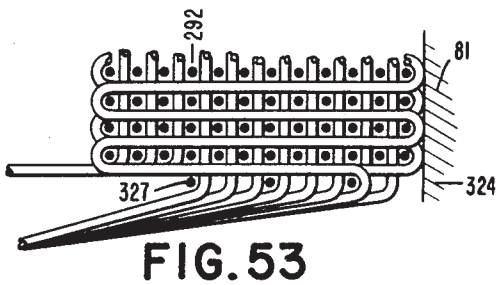
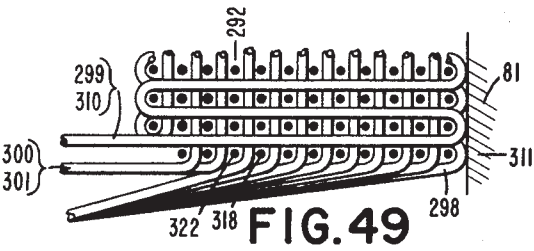
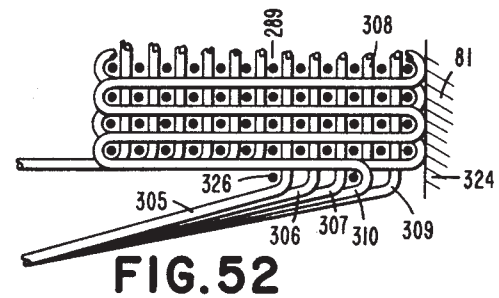
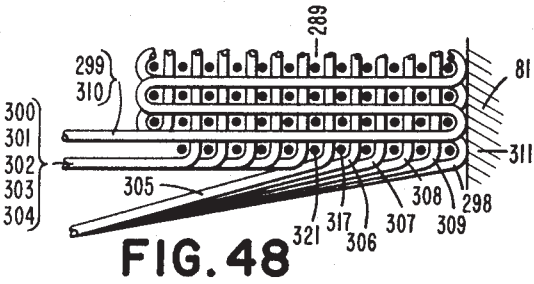
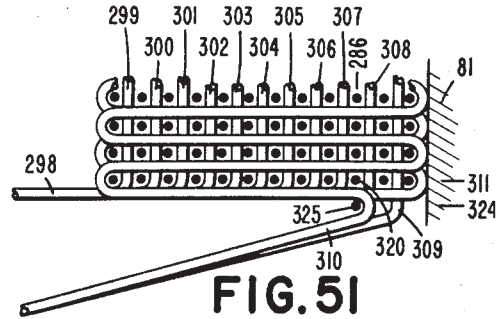
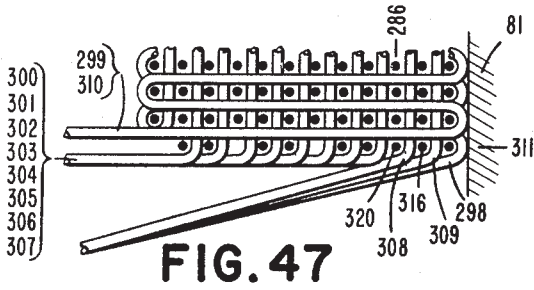


FIG. 38







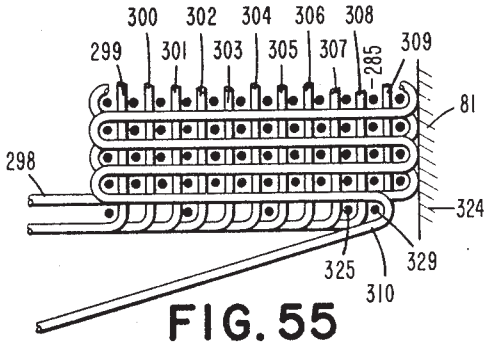


FIG. 55

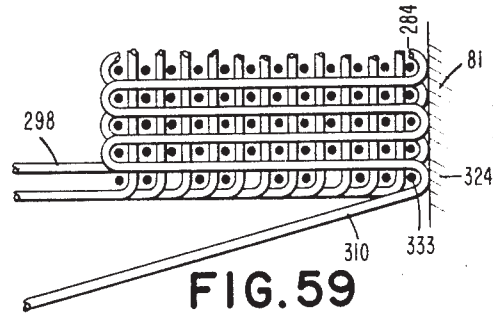


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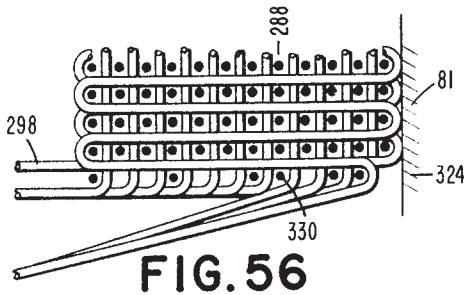


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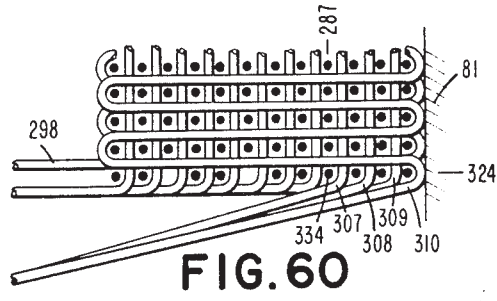


FIG. 60

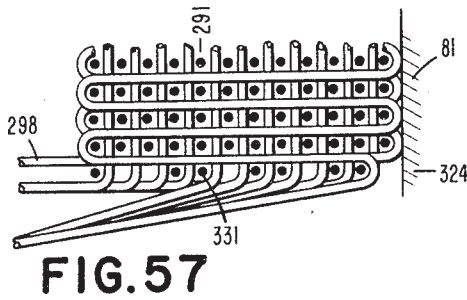


FIG. 57

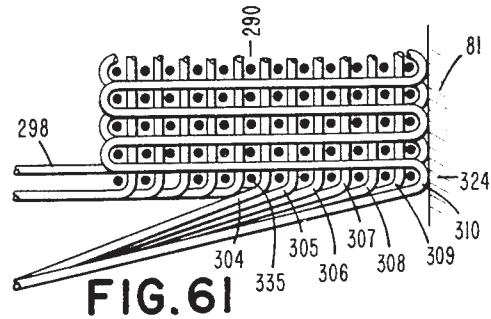


FIG. 61

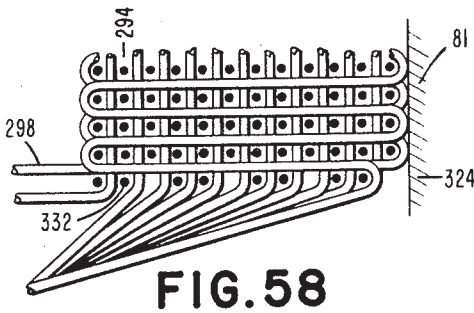


FIG. 58

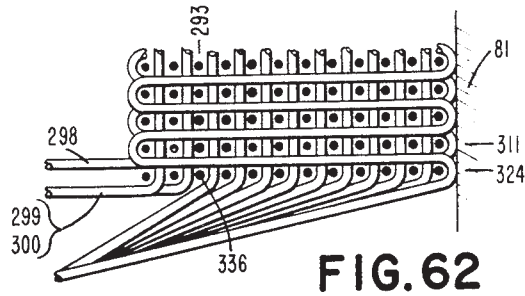


FIG. 62

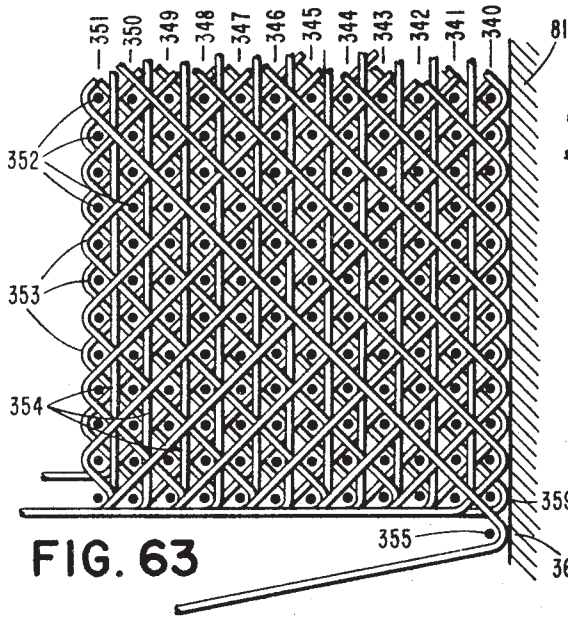


FIG. 63

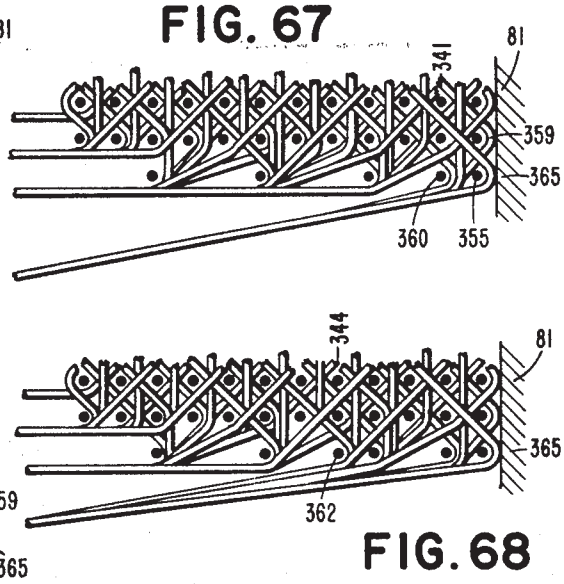


FIG. 67

FIG. 68

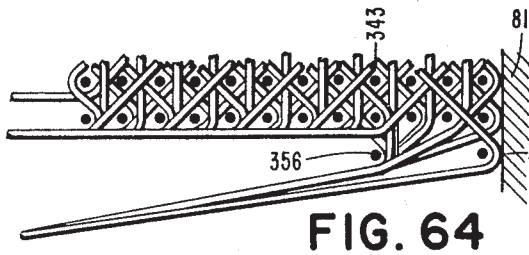


FIG. 64

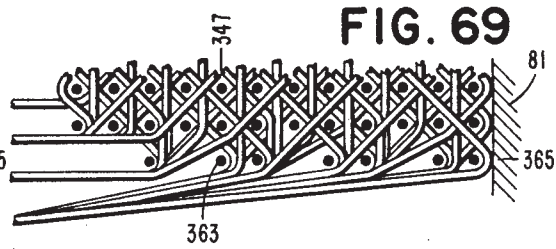


FIG. 69

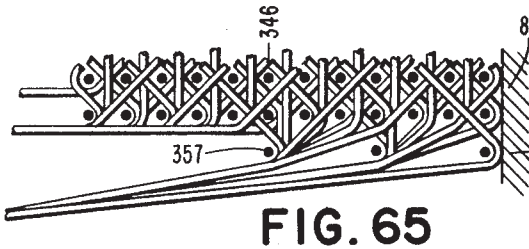


FIG. 65

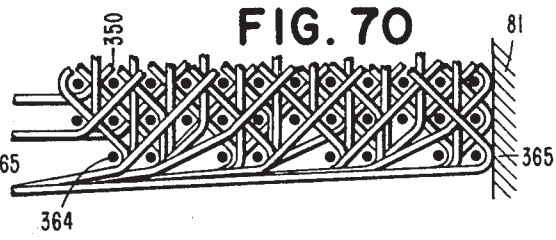


FIG. 70

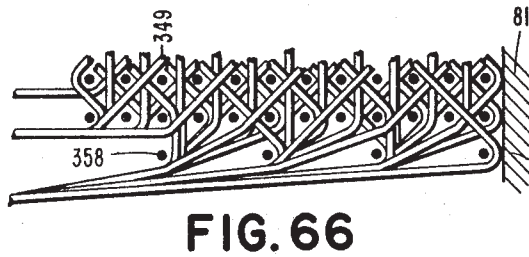


FIG. 66

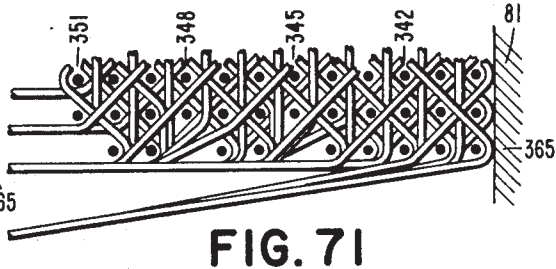


FIG. 71

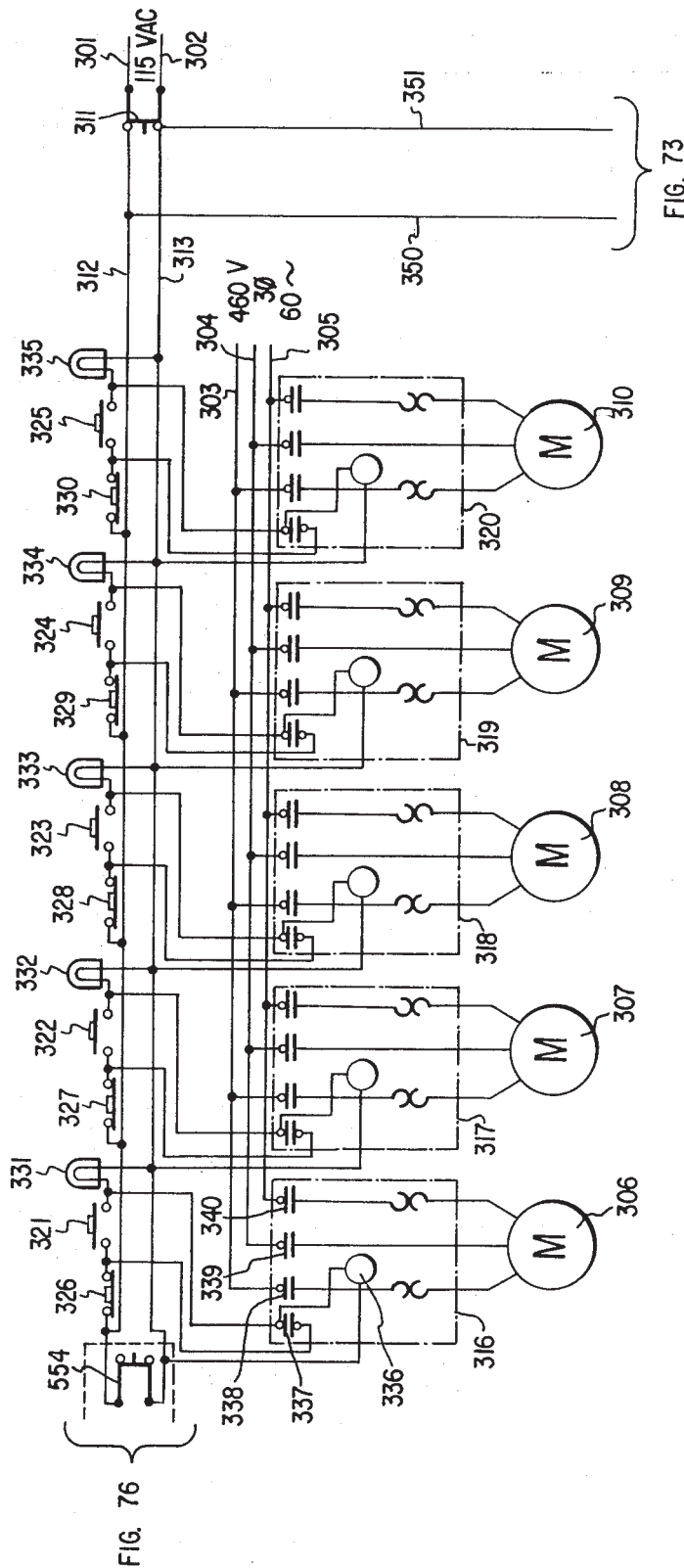


FIG. 73

FIG. 72

FIG. 76

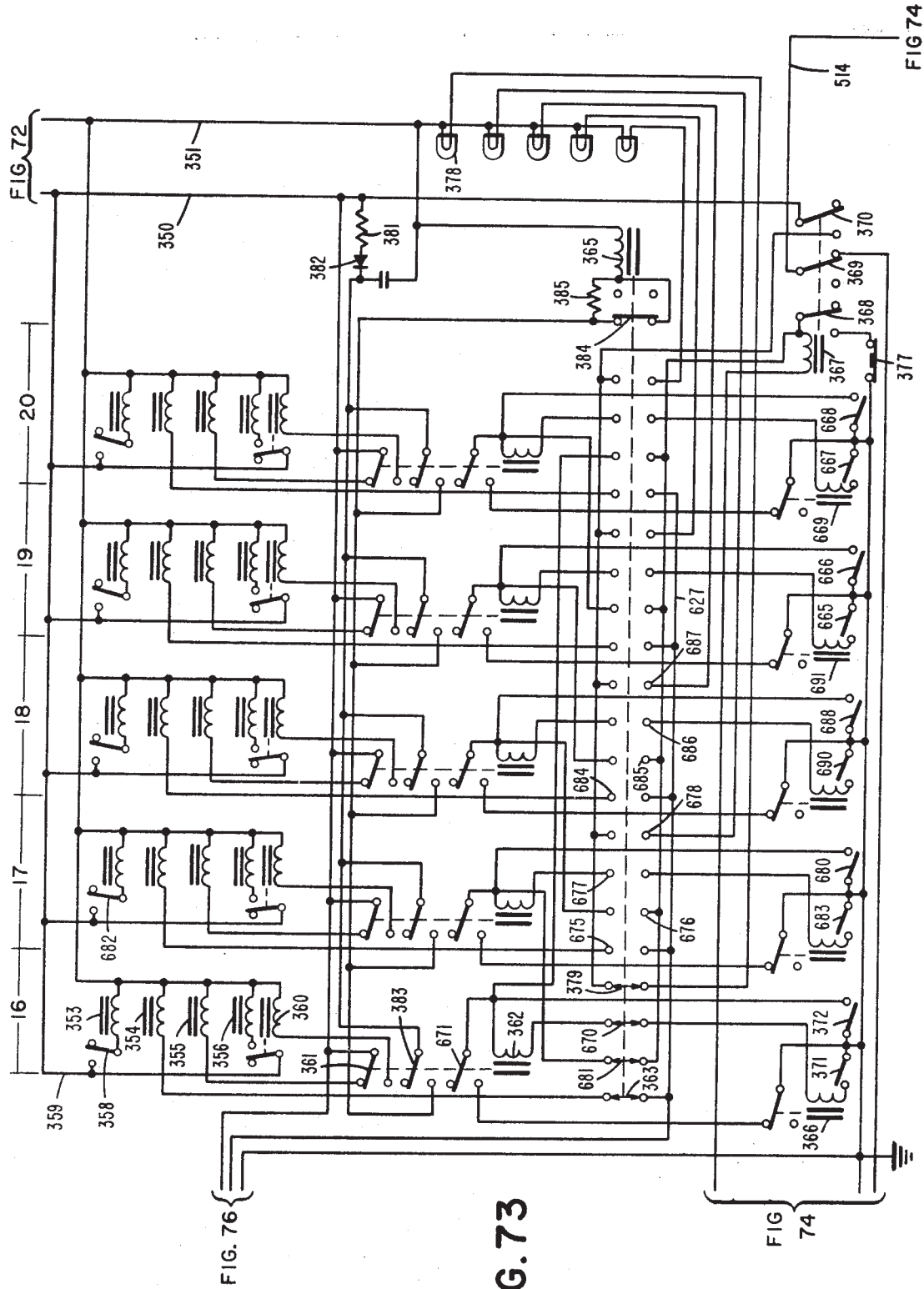


FIG. 76

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FIG. 74

FIG. 74

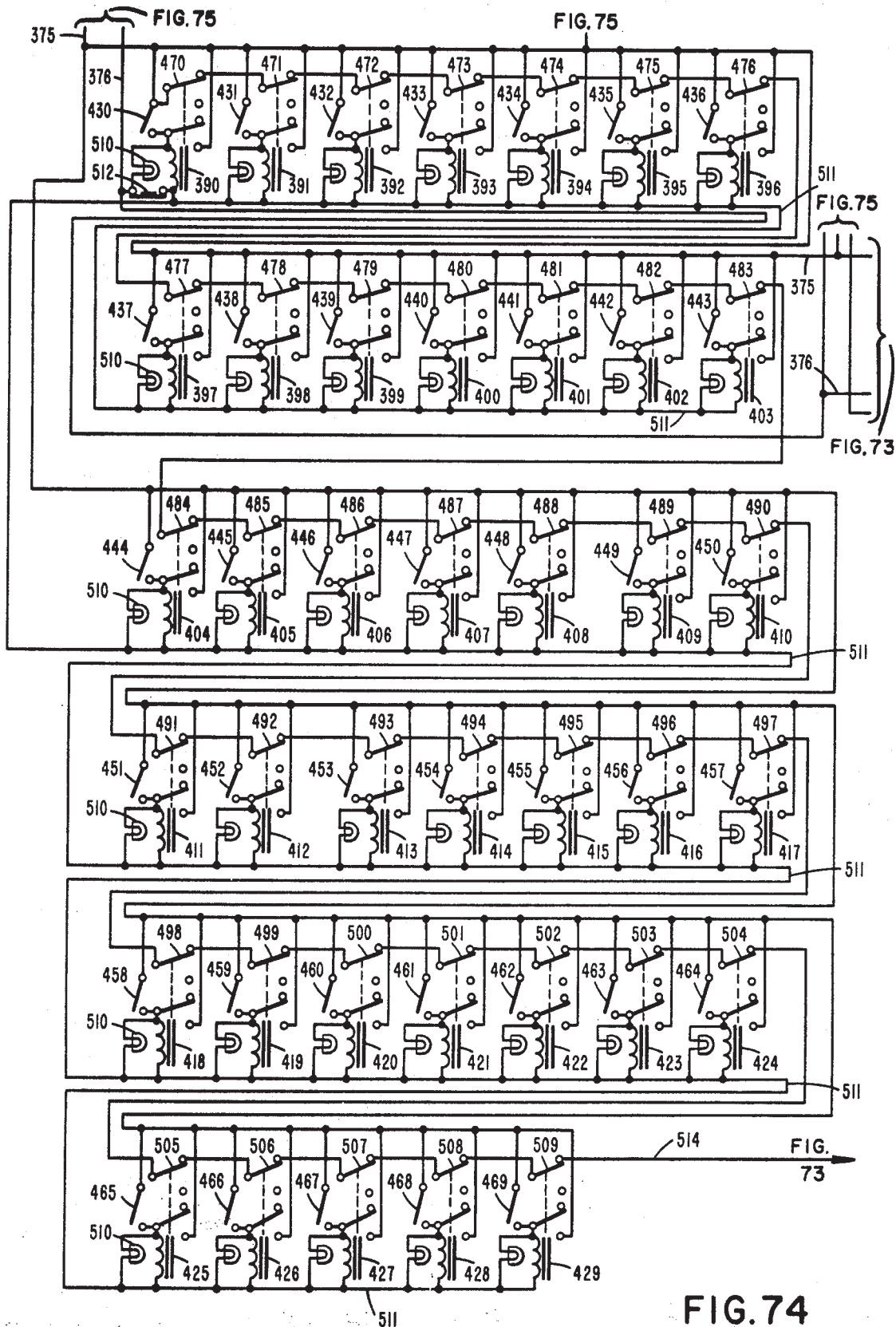
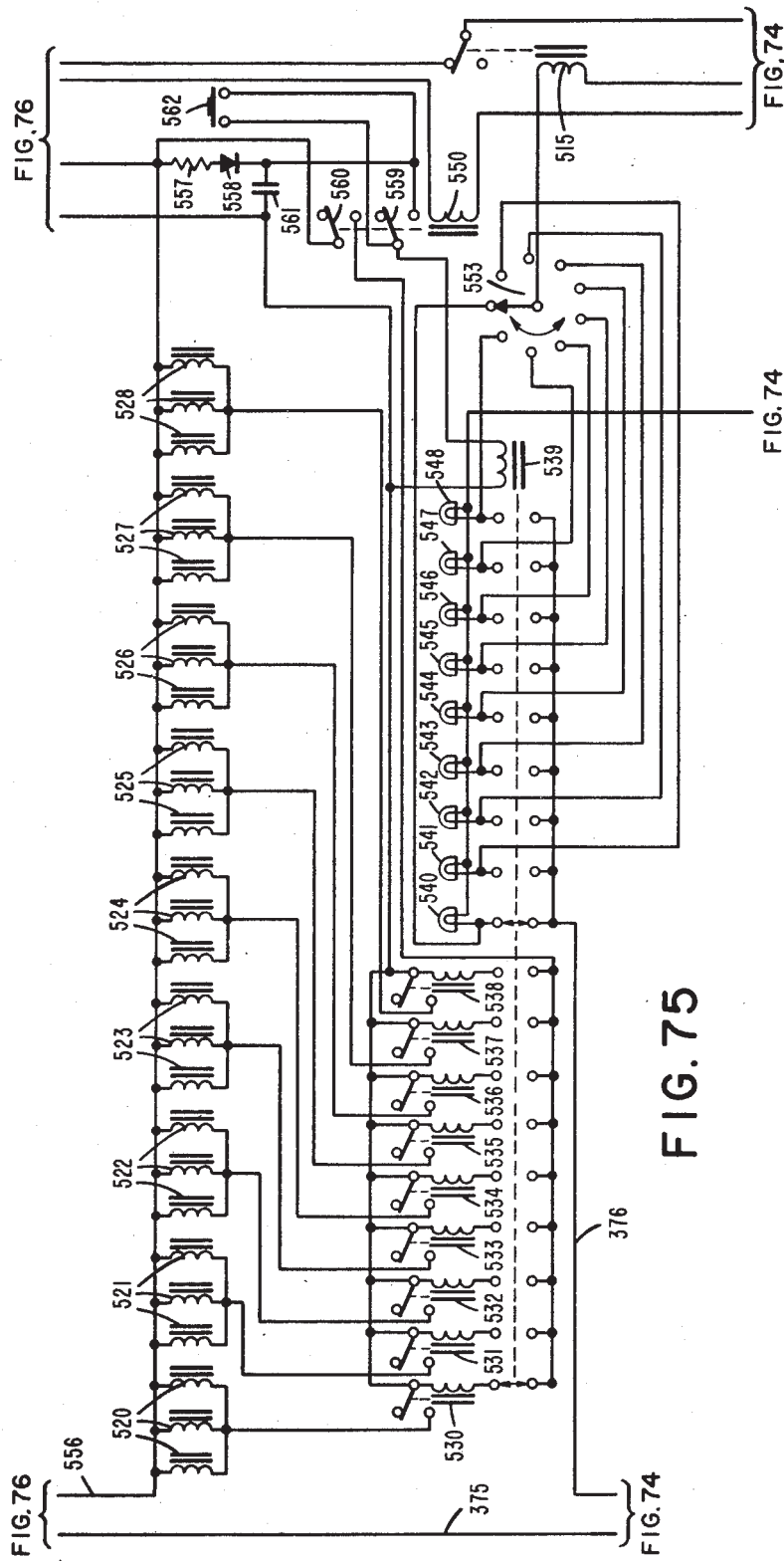


FIG. 74





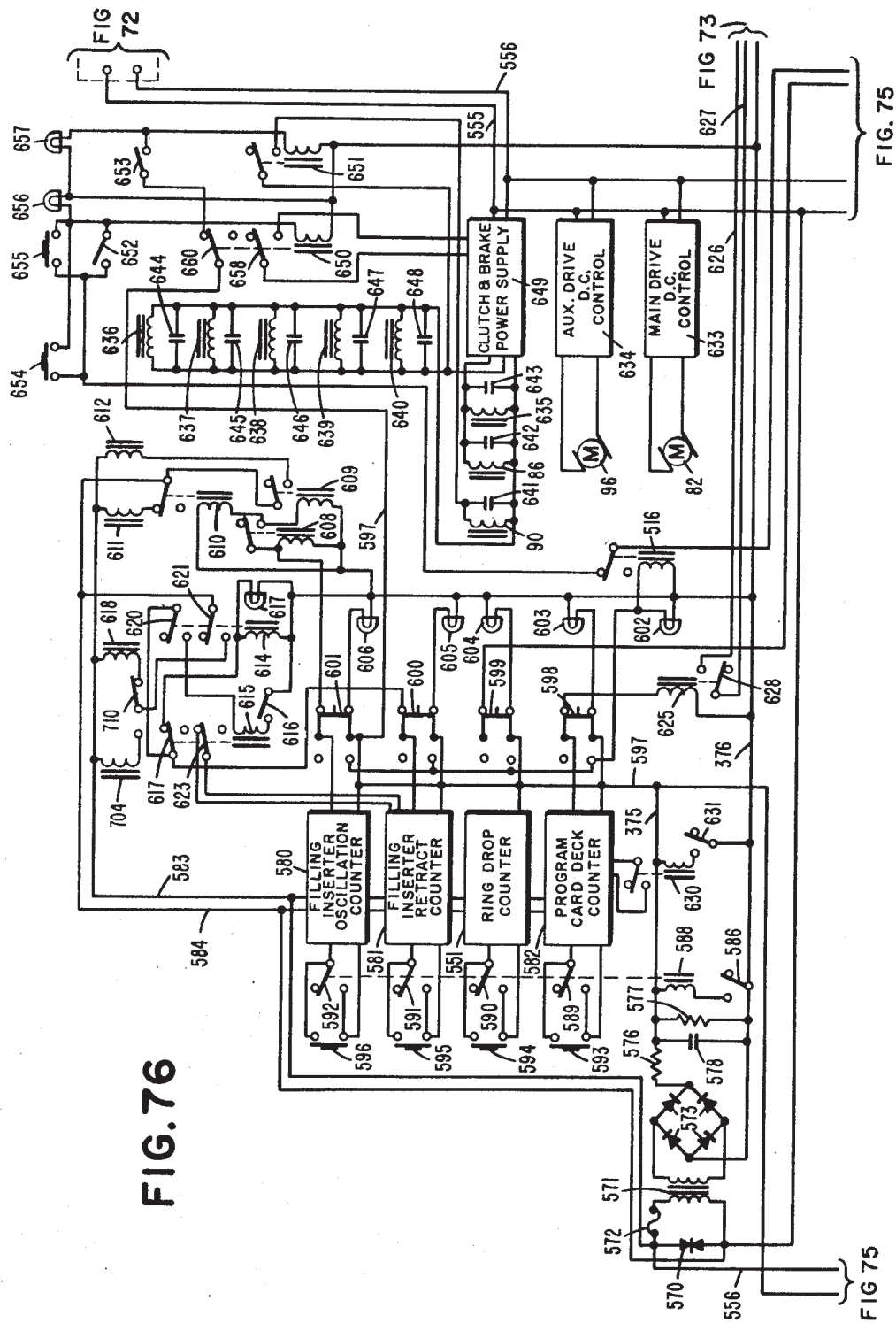


FIG. 76

FIG. 75

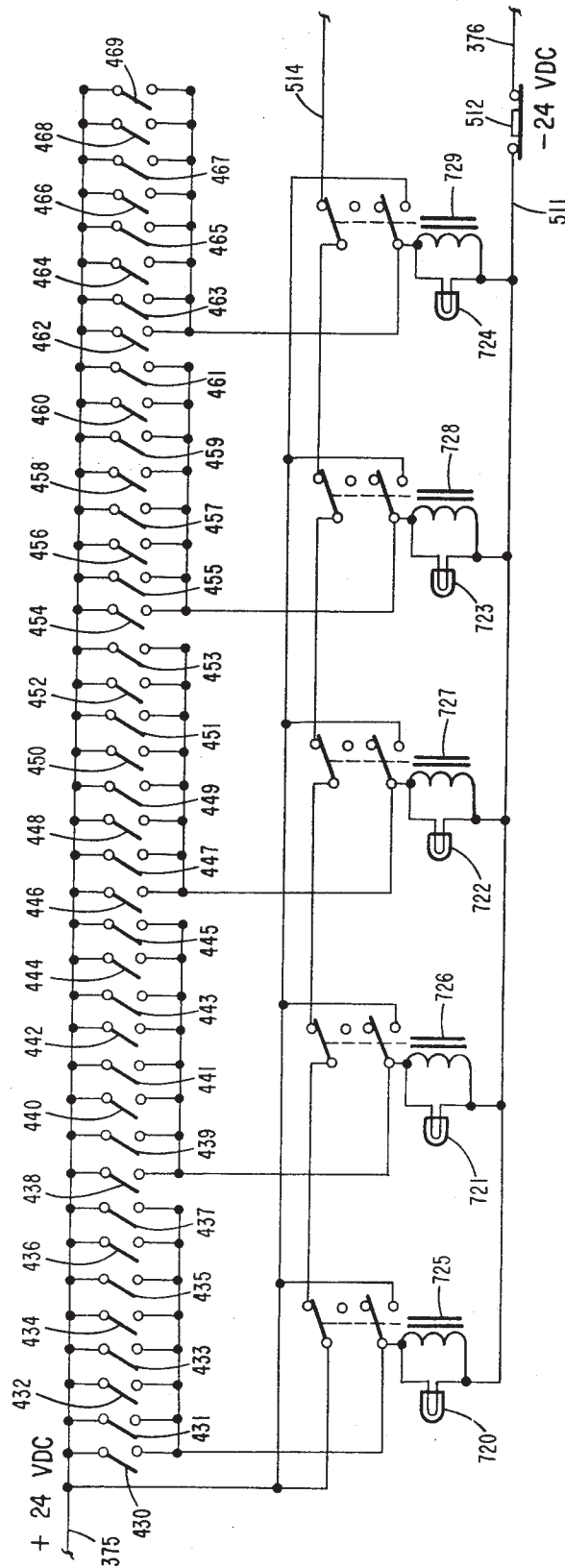


FIG. 77

## CIRCULAR WEAVING APPARATUS PRODUCT AND PROCESS

This application is a division of application Ser. No. 793,921, filed Dec. 31, 1968.

### BACKGROUND OF THE INVENTION

#### 1. Field of the Invention

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

#### 2. Description of the Prior Art

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

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

Other shaped fabrics are generally disclosed in U. S. Pat. Nos. 3,102,559, 3,090,406 and 3,234,972 to Koppelman et al. Fabrics of this type are woven on a flat loom using one or more shuttles and Jacquard means to

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

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

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

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

### SUMMARY OF THE INVENTION

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

be combined into a single yarn system comprised of a plurality of yarn planes which traverse the filling yarn planes.

The apparatus for producing the fabrics of this invention includes a frame which is provided with four levels. The frame as shown in FIG. 1 supports on the fourth level five Jacquard heads which are substantially equidistantly spaced about the vertical axis of the frame. Each Jacquard head includes a multiple actuator system for raising and lowering the knives and grates, a multiple card chain and index system, an hydraulic system for actuation thereof, and a means for suspending selected hooks out of engagement with the knives and grates whereby the yarns associated with the suspended hooks are maintained in a stationary position until they are to be woven into the fabric. The third level which is immediately below the fourth level of the frame includes a plurality of comberboards which are substantially equidistantly spaced about the vertical axis of the apparatus and reside in a common horizontal plane. The comberboards receive and vertically align the plurality of heddles which are connected to the Jacquard hooks.

The second and third levels jointly support a plurality of eye boards which are substantially equidistantly spaced around the vertical axis of the apparatus and lie in vertical planes which are substantially parallel to said vertical axis. The eye boards receive the warp yarns from the creels and order the same so that the warp yarns are presented to the heddle mail eyes in substantially parallel alignment. The second level of the frame also mounts a main drive gear support in a horizontal position which in turn supports for rotation the main drive gear. The main drive gear support and the main drive gear are annular in shape and are concentrically arranged about the vertical axis of the apparatus with the main drive gear being rotated in a plane about the vertical axis of the apparatus. The main drive gear has rigidly mounted thereon a plurality of fabric compactors which are substantially equidistantly spaced about the main drive gear and are radially positioned to point toward the mandrel. The main drive gear support has affixed thereto a plurality of vertically aligned filling yarn inserter drive gear supports and a circumferentially arranged disjointed rail. The filling yarn inserter drive gears are vertically journaled for rotation in the filling yarn inserter drive gear supports. These gears are rotated by the motion of the main drive gear. Each segment of the support rail encompasses a short arc about the outer circumference of the main drive gear support and is positioned immediately above each of the filling yarn inserter drive gears. The filling yarn inserter is adapted to simultaneously engage the circumferentially arranged disjointed rail and at least one of the filling yarn inserter drive gears. The filling yarn inserters are mounted extending radially inward toward the vertical axis of the apparatus between the aforementioned fabric compactors. The filling yarn inserters and the fabric compactors move in unison in horizontal planes normal to the axis of the apparatus and are adapted to be extendable and retractable to enable weaving of fabrics of varying diameters upon the surface of a given shaped mandrel. The warp yarns are aligned to pass freely between the plurality of filling yarn drive gear supports without engagement therewith

by means of the heddle array provided by the comberboards.

The mandrel may be of most any shape and it in combination with the Jacquard head program defines the resulting curvilinear shape of the three-dimensional fabric. The mandrel, which is raised and lowered by means of a mandrel elevator, has its upper end maintained in vertical alignment with the vertical axis of the apparatus by means of a spider guide engaging a plurality of vertically aligned parallel rods which are positioned between and affixed to the third and fourth levels of the frame. The spider guide is disconnectably attached to the mandrel and is adapted for movement along the vertical rods with the path of motion being along the vertical axis of the apparatus. Thus, as the mandrel elevator raises or lowers the mandrel, the spider guide moves therewith and prevents misalignment between the mandrel's longitudinal axis and the vertical axis of the apparatus.

The apparatus of this invention includes a plurality of concentrically arranged rings which are provided as a means of supporting warp yarn ends which are added to the fabric during the weaving of a geometrically-shaped product such as a truncated cone or any product having an ever-increasing cross-sectional area. The concentric rings are initially located by means of solenoid actuated ring supports. The solenoid actuated ring supports are secured to an annular member which is substantially concentrically aligned with the vertical axis of the apparatus and which is supported by the vertically mounted rods of the mandrel guide. A plurality of warp yarn ends is laced under the lower edge of and tied to the top of each of the concentric rings whereby the warp yarns affixed thereto are maintained in a ready position for weaving into the fabric in accordance with the weaving program. The concentric rings are provided with a plurality of arms each of which initially rest on a selected solenoid actuated ring support. When the solenoids are electrically energized the ring supports are retracted to release the concentric ring arms thus enabling the concentric rings to individually drop into close proximity to the woven fabric on the surface of the mandrel whereupon the warp yarns are woven systematically into the fabric. While the concentric rings of this invention are not adaptable for use in the weaving of every type of fabric configuration, they are highly useful where the cross-sectional area of the fabric is continuously or sequentially increasing throughout the overall length thereof. Thus, the warp yarn ends attached to the rings are held out of the weaving shed until needed to provide for increased fabric diameters thus saving quantities of yarn. Further, the time required to cut the dangling warp ends from the resulting woven fabric is significantly reduced.

The creels of this invention each include a plurality of horizontally arranged shafts each of which mount a plurality of spools. Each spool is provided with a rewind spring or other means so that a constant tension is maintained on the particular warp yarns supplied to the apparatus. Also, the rewind spring or other means is adapted to rewind a length of warp yarn onto a spool to take-up slack in the warp yarn formed in the shedding process.

The mandrel elevator and the main drive gear are simultaneously driven by an electric motor located



beneath the third floor of the frame so as to synchronize the movement of the mandrel with the rate of weaving, the electric motor being connected to the mandrel elevator and main drive gear by means of electric clutches. Thus, the Jacquard head in combination with the filling yarn inserters function to lay in and weave yarn about the mandrel while simultaneously therewith the mandrel is being raised by the mandrel elevator at precisely the rate of weaving. Alternatively, a separate synchronized stepping motor of the reversing type may be employed to actuate the mandrel elevator whereby the mandrel may be oscillated during elevation to facilitate pick insertion during weaving. The mandrel elevator may also be raised and lowered by means of a second electric motor which is connected to the drive shaft by means of an electric clutch. The second motor and the connected electric clutch is operable to raise and lower the mandrel only when the first electric motor is disengaged from the mandrel elevator by means of an electric clutch. Thus, the electric clutch connecting the second motor to the mandrel elevator can only be energized to raise and lower the mandrel elevator when the electric clutch connecting the first motor to the mandrel elevator has been de-energized.

Each of the filling yarn inserters is provided with an electric interlock stop means so that upon the breaking of a filling yarn, the main drive gear and the mandrel elevator are stopped simultaneously and substantially instantaneously by the disengagement of the respective electric clutches and the engagement of a plurality of electric brakes.

It can be seen that the apparatus and process of this invention is adaptable to weave fabrics of various shapes and pattern designs. The electrical system coordinates the function of the Jacquard heads and the movement of the mandrel elevator to produce a particular programmed shaped fabric having a given wall thickness. In this circular type weaving machine, it is necessary only to have one filling yarn inserter which is equivalent to the commonly known shuttle; however, it is desirable to have a plurality of filling yarn inserters to increase the rate of productivity of the apparatus. Further, it is necessary to have at least one more Jacquard head than filling yarn inserters; therefore, if only one filling yarn inserter were employed, it would be necessary to have at least two Jacquard heads to enable one of the Jacquard heads to change the shed it controls while the filling yarn inserter is moving through the shed of the other Jacquard head. The relationship of the number of Jacquard heads to the number of filling yarns inserters may be stated as follows,

$$\frac{\text{(No. of Jacquard heads)} - \text{(No. of filling yarn inserters)}}{1} \quad (1)$$

This relationship is necessary to provide at least one shed area that is unoccupied by a filling yarn inserter during the period of time required for the changing of the shed by its respective Jacquard head.

However, it may be desirable to weave a shaped thick-walled fabric which does not define an envelope such as for example a trough or boat hull. In this case the relationship of the number of Jacquard heads to the number of filling yarn inserters may be less than one

since the shed may be changed while the filling yarn inserters are outside the area thereof. It may be desirable when weaving such articles to provide suitable selvages in order to minimize raveling.

The Jacquard heads of this invention are preferably of the negative, double-lift type. In a negative Jacquard head a card program hole permits its corresponding hook to remain disengaged from the knife while a blank space allows its corresponding hook to be actuated into engagement with the knife. Consequently, yarns which have not been programmed into the fabric lie above the surface of the fabric. This is necessary since the three-dimensionally shaped, thick-walled fabric of this invention is woven directly on the surface of a mandrel. In double lift Jacquard heads the knives and grates thereof are caused to move in opposite directions from a center shed position thus enabling the obtaining of a warp yarn shed having a greater than normal depth for the easy passage of the filling yarn inserter therethrough. A standard Jacquard head, which does not lower those hooks not engaged with the knives thereof may be employed when the yarn carrier mounted on the filling yarn inserter is extremely narrow and thus is adapted to clear the narrower shed created thereby.

While it is not shown, the creels are adapted for lateral movement by means of overhead concentrically aligned rails to enable moving the creels in either direction to provide access thereto and to the interior portions of the apparatus. Also not shown is a hoist which is mounted above the apparatus and which is adapted to be connected to the eyelet in the upper portion of the mandrel so that upon the completion of the weaving of a particular fabric, the mandrel and fabric are withdrawn from the apparatus whereupon the fabric may be removed from the mandrel. While the mandrels shown are integral in structure, for certain weave patterns and fabric designs, it may be necessary to have a multi-structure representing the mandrel or, alternately a collapsible mandrel. For example, a fabric woven about a mandrel as shown in FIG. 26 could not be slidably removed therefrom; therefore, such a mandrel should either be separable in the middle thereof or collapsible.

The apparatus is additionally provided with an electronic counter to enable maintaining a running count of the number of filling yarn picks as they are woven into the fabric so that in the event the weaving process is stopped for any reason such as a power or mechanical failure weaving of the fabric can be resumed without impairing the continuity thereof. The electronic counter control comprises a stationary reed switch mounted onto the main drive gear support and a permanent magnet affixed to the main drive gear. As the main drive gear rotates the permanent magnet affixed thereto passes over the reed switch, the reed switch closes due to the magnetic field of the magnet and thus completes the circuit to the electronic counter which records that particular count.

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

Another object of this invention is to provide a shaped, thick-walled fabric which is comprised of a plurality of yarn systems each of which defines a plurality

of yarn planes with the yarn planes of each yarn system being distinct and traversing selected yarn planes of the other yarn systems.

Another object of this invention is to provide a process for weaving a thick-walled, three-dimensionally shaped fabric upon the surface of a mandrel.

Another object of this invention is to provide an apparatus which includes Jacquard heads and a mandrel for integrally weaving a thick-walled, three-dimensionally shaped fabric upon the surface of the mandrel, the fabric pattern being determined by the Jacquard heads and the three-dimensional shape being determined by the Jacquard heads in combination with the mandrel.

Another object of this invention is to provide a circular type weaving machine which is capable of weaving thick-walled fabrics of irregular shapes which may be used as airplane wings, boat hulls or the like.

Another object of this invention is to provide a circular type weaving machine with a novel filling yarn inserter.

Another object of this invention is to provide a Jacquard head hook levitator which is adapted to hold certain Jacquard hooks out of contact with the moving knives so that the warp yarns associated therewith are not incorporated into the shed but remain stationarily fixed above the shed.

Another object of this invention is to provide a circular type weaving machine with a fabric compactor, the fabric compactor being adapted to compact the yarns into the body of the fabric.

Another object of this invention is to provide a process for integrally weaving a three-dimensionally shaped fabric in accordance with a predetermined pattern which produces a curvilinear design and a fabric thickness, the woven fabric being comprised of yarn systems which lie in a plurality of distinct planes.

Another object of this invention is to provide a creel with spools which are adapted to maintain a uniform tension on a warp yarn while also being adapted to rewind a given length of the warp yarn to prevent the development of slack therein.

Another object of this invention is to provide a mandrel elevator and a mandrel guide for raising and lowering a mandrel along a given vertical path.

Another object of this invention is to provide means for coordinating the movement of the mandrel at a rate equal to that at which the fabric is woven.

Another object of this invention is to provide a braking system in cooperation with filling yarn inserters so that upon the breaking of the filling yarn, the entire apparatus is substantially instantaneously stopped.

Another object of this invention is to provide the circular type weaving machine with a plurality of concentric rings having affixed thereto additional warp yarns that are programmed to be added sequentially to the fabric as the diameter thereof is increased to enable maintaining a substantially constant fiber density throughout the vertical length of the woven fabric.

Another object of this invention is to provide the Jacquard heads with a hydraulic means for actuating the Jacquard heads and for indexing the program card deck index cylinder and the pattern card deck index cylinder and the pattern card deck index and card reading cylinder.

Further objects and advantages of this invention will be set forth or become apparent from the following description of a preferred embodiment thereof, to which the invention is by no means restricted, reference being made to the accompanying drawings in which:

#### DESCRIPTION OF THE DRAWINGS

FIG. 1 is plan view of the apparatus showing the Jacquard heads being concentrically arranged and substantially equidistantly spaced about the vertical axis of the apparatus and the creels supplying yarn to the apparatus;

FIG. 2 is a section view taken along line 2—2 of FIG. 1 showing the weaving plane and the major elements of the apparatus;

FIG. 3 is a section view taken along line 3—3 of FIG. 2 showing the concentric rings, the mandrel guide for centering the upper portion of the mandrel, and the arrangement of the comber boards;

FIG. 4 is a fragmentary section view taken along line 4—4 of FIG. 3 showing the comber board supports and two comber boards in side-by-side relationship;

FIG. 5 is a plan view of a comber board showing the openings through which selected heddles pass;

FIG. 6 is a fragmentary section taken along line 6—6 of FIG. 2 showing a portion of the concentric rings mounted on solenoid actuated ring supports;

FIG. 7 is a fragmentary section view taken along line 7—7 of FIG. 6 showing selected concentric rings having engaged and having been raised by the woven fabric with the remainder of the concentric rings being supported by the solenoid actuated ring supports;

FIG. 8 is a fragmentary section view taken along line 8—8 of FIG. 6 showing a solenoid actuated ring support mounting one arm of a concentric ring;

FIG. 9 is the view of FIG. 8 showing the solenoid having been actuated and having allowed the concentric ring arm to fall onto the stationary support ring;

FIG. 10 is a fragmentary section view taken along line 10—10 of FIG. 2 showing the alternating arrangement of the filling yarn inserters and the fabric compactors about the mandrel;

FIG. 11 is a section view taken along line 11—11 of FIG. 2 showing the drive, the mandrel elevator, and the area occupied by the lingos in cross-section;

FIG. 12 is a section taken along line 12—12 of FIG. 10 showing a filling yarn inserter and a fabric compactor respectively operating to lay in a filling yarn in the shed and to compact the yarn into the fabric;

FIG. 13 is a fragmentary section view taken along line 13—13 of FIG. 12 showing in plan the arrangement of the filling yarn inserter drive gears which are mounted on the main drive gear support in meshing engagement with the main drive gear;

FIG. 14 is a perspective view of a filling yarn inserter in an extended position;

FIG. 15 is a plan view showing the filling yarn inserter in a retracted position;

FIG. 16 is a section view taken along line 16—16 of FIG. 15 showing the relationship of the slides to the guides;

FIG. 17 is a section view taken along line 17—17 of FIG. 15;



FIG. 18 is a fragmentary elevation view of FIG. 14 showing the filling yarn break detector and a filling yarn inserter drive gear in meshing engagement with the filling yarn inserter;

FIG. 19 is a fragmentary end view of FIG. 14 showing a filling yarn inserter tip positioning star wheel in engagement with the filling yarn inserter star wheel drive pin;

FIG. 20 is a partial section perspective view taken along the line 20—20 of FIG. 10 depicting the relationship of a reed switch to its actuating means;

FIG. 21 is a perspective view of the fabric compactor in an extended position;

FIG. 22 is a plan view of the fabric compactor showing the same in a retracted position;

FIG. 23 is a section view taken along line 23—23 of FIG. 21 showing the fabric compactor secured to the main drive gear which in turn is rotatably mounted on the main drive gear support;

FIG. 24 is a partially sectioned perspective view of a conically-shaped mandrel adaptable for use in combination with the apparatus of this invention and upon the surface of which the fabric is woven;

FIG. 25 is a perspective view of a cylindrically-shaped mandrel;

FIG. 26 is a perspective view of a hyperboloid of revolution of one sheet-shaped mandrel;

FIG. 27 is a perspective view of a mandrel, the upper half of which is conically shaped while the lower half of which has the shape of a hexagonal pyramid;

FIG. 28 is a perspective view of a mandrel having an elliptical cross-sectional shape and being mounted on an eccentric axis;

FIG. 29 is a partial section through a shed showing a filling yarn inserter passing therethrough and showing an eye board receiving the warp yarns from the creels;

FIG. 30 is a fragmentary elevation view of a creel showing the same provided with a plurality of spool stations;

FIG. 31 is a partial section view taken along line 31—31 of FIG. 30 showing a spool station having a plurality of spools and showing the rewind springs mounted on a shaft and exerting a force on the spools;

FIG. 32 is a plan view of an unstressed rewind spring;

FIG. 33 is a fragmentary elevation view of a Jacquard head showing the same in combination with a hook levitator;

FIG. 34 is a perspective view of the Jacquard head levitator support plate;

FIG. 35 is a fragmentary section view taken along lines 35—35 of FIG. 33 showing the levitator means for holding and releasing the hooks;

FIG. 36 is a schematic diagram showing the hydraulic system for actuating the Jacquard head lift cylinders, the program card deck index cylinder and the pattern card deck indexing and reading cylinder;

FIG. 37 is a schematic block diagram of the electrical circuit;

FIGS. 38 through 62 are section views through a first fabric embodiment showing in sequence the manner in which two decks of filling yarns are woven into the fabric;

FIGS. 63 through 71 are section views through a second fabric embodiment showing portions of the sequence for weaving one deck of filling yarn into the fabric;

FIG. 72 is a schematic diagram of the electrical circuit associated with the hydraulic drive motors;

FIG. 73 is a schematic diagram of the electrical circuit controlling the action of the Jacquard heads;

FIG. 74 is a schematic diagram of the yarn filling break detector circuit;

FIG. 75 is a schematic diagram of the warp yarn addition control circuit;

FIG. 76 is a schematic diagram of the apparatus programming and drive control circuit; and

FIG. 77 is a schematic diagram of an alternative yarn filling break detector circuit.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

In reference to FIG. 2 which is a cross-section taken through the center of the apparatus and which shows the major components thereof, the frame 10 includes a plurality of upright legs 11 which serve to support the elements which collectively comprise the apparatus of this invention. Legs 11 mount on a first level and support a second level 14, a third level 13 and a fourth level 12. Rigidity for frame 10 is provided by means of braces 15 which are connected to legs 11 and fourth level 12, braces 15 mounting third level 13 horizontally.

#### JACQUARD HEADS

The Jacquard heads 16, 17, 18, 19 and 20 as shown in FIG. 1, reside on the fourth level 12 and are substantially equidistantly and radially arranged about the vertical axis of the apparatus. Each of the Jacquard heads is of the negative, double lift type to maintain the warp yarns in the upper shed prior to their introduction into the weave pattern and to provide for a greater shed depth. Thus, as shown in FIGS. 33 and 35, upon the actuation of the Jacquard head the knives 22 rise while the grates 23 drop. Each Jacquard head is provided with a multiple card deck system as shown in FIG. 35. Pattern card chain 25 which is comprised of a plurality of cards 26 is supported and sequentially indexed by pattern index cylinder 27. Program card chain 30 is supported and selectively indexed by program index cylinder 31 and card guide 32 and is comprised of a plurality of cards 33. Index cylinders 27 and 31 are substantially square in cross-section and are mounted for rotation on shafts 35 and 36, respectively. Each surface of pattern index cylinder 27 is provided with a plurality of openings 37, one for each needle as will hereinafter be described, and a pair of card positioning pins 38. For the purposes of this invention, the pattern card chain 25 is adapted to program the basic pattern which is then varied by the cards of program card chain 30. Thus, the pattern index cylinder 27 rotates with each Jacquard actuation whereas the program index cylinder 31 which controls the program card chain 30 rotates only selectively to vary the pattern as established by the pattern card chain 25.

While the action of the Jacquard heads is conventional, modifications have been made to adapt multiple card chain systems thereto. A plurality of needles 40 are arranged to match a series of openings 37 in pattern index cylinder 27. Each of needles 40 is connected to a selected hook 42 which in turn is connected to a plurality of heddles 44.

Each of the Jacquard heads is further provided on the top thereof with a hook levitator 46. The hook levitator 46 is adapted to position selected warp yarns out of the warp yarn shed by maintaining hooks 42 and, resultingly, the connecting heddles 44 in a position which is out of engagement with the knives 22. Hook levitator 46 is comprised of a stationary plate 47 which is supported on top of the Jacquard head above the area in which the hooks reside and a series of movable bars 48 which are adapted to slide on the upper surface of plate 47. The plate 47 is provided with a series of elongated and parallel slots 49 through which selected hooks are positioned prior to the operation of the Jacquard head. It can be seen that the hooks 42 are arranged in a series of parallel rows which correspond to the slots 49 in plate 47 and also arranged in transverse parallel rows perpendicular to the direction of slots 49. The bars 48 are provided perpendicular to the direction of the slots 49 and are slidably movable in that transverse direction upon the surface of plate 47. Thus, as more warp yarns are required for the warp yarn shed, a selected bar 48 is actuated to engage and to slide out of engagement with plate 47 the transverse parallel row or rows of hooks associated with the bar 48. Bars 48 may be energized by solenoid switches (not shown) which could be programmed to remove the hooks from plate 47 simultaneously with the dropping of the corresponding concentric ring to which those particular warp yarns are affixed.

In operation, a card from pattern card chain 25 is located in position for reading by means of pattern index cylinder 27 and a selected card from the program card chain 30 is lowered into alignment with the selected card of pattern card chain 25 by the rotation of program index cylinder 31. Index cylinder 27 then moves laterally into engagement with the needles 40. Under pressure, some needle ends pass through aligned holes in the adjacent and contiguous cards of the respective card chains and enter perforated openings in the pattern index cylinder 27. However, some needles may strike unperforated areas in the cards of either card chain 30 or 25 whereupon those needles and their corresponding hooks are pushed by the pressure of the index cylinder 27 so as to be positioned to engage and be raised by knives 22. Since some hooks are not raised by the respective knives, their heddles remain down with the hooks 42 resting on the grates 23, so that upon the lowering of grates 23, the warp yarns running through the mail eyes of the heddles connected to those hooks are lowered and form the bottom plane of the shed. Those hooks being raised by knives 22 in turn raise selected heddles which position the warp yarns running through the mail eyes thereof in a raised position to form the upper plane of the shed.

#### HYDRAULIC SYSTEM FOR JACQUARD HEADS

Each of the Jacquard heads is actuated by a hydraulic system as disclosed in FIG. 36. The hydraulic system includes the hydraulic lift cylinders 52 which are adapted to raise the knives 22 and lower the grates 23 simultaneously, the hydraulic cylinder 53 which provides for the reciprocation and rotation of the pattern card chain index cylinder 27 sequentially, and the hydraulic cylinder 54 which is adapted to actuate the program card chain index cylinder 31. The hydraulic

system further includes a reservoir 55 and a constant delivery pump 56 which is driven by an electric motor 57, the pump drawing hydraulic fluid from the reservoir 55 through the line 58 and the strainer 58a. The hydraulic fluid is pumped through the check valve 59 which prevents the back flow of the fluid when either the relief valve 66 or the solenoid by-pass valve 67 is open. From the check valve 59 the pressurized fluid is distributed to the components of the system by means of piping 58, junction 60, and lines 61, 62, 63 and 65. The line 61 supplies hydraulic fluid to the lift cylinders 52 through the metering valve 61a and the four-way solenoid valve 69. Additionally line 61 supplies hydraulic fluid to the gas pressurized accumulator 64 by means of line 65. The line 62 supplies hydraulic fluid to the pattern card chain hydraulic indexing cylinder 53 through the metering valve 62a and the four-way solenoid valve 73. The line 63 supplies hydraulic fluid to the program card chain hydraulic indexing cylinder 54 through the metering valves 63a and the four-way solenoid valve 76. The metering valves 61a, 62a, and 63a provide the means for controlling the rate of motion of the respective hydraulic cylinders 52, 53, and 54. The gas pressurized accumulator 64 provides a reservoir of pressurized fluid to reduce the pressure differential in the system coincident with the actuation of the cylinders 52, 53, and 54.

The pressure in the system is controlled by the relief valve 66 which is series connected to the pressure side of the pump 56 by means of the line 58. Additionally there is provided the two-way solenoid by-pass valve 67 which is piped in parallel with the relief valve 66. The by-pass valve 67 is programmed (the electrical circuit to be hereinafter described) to provide for continuous cycling of the hydraulic fluid during the interim period between Jacquard head cycles whereby heat build-up in the hydraulic system is substantially reduced.

The hydraulic lift cylinders 52 are actuated upon the energization of the four-way solenoid valve 69 which permits pressurized fluid flow in the line 70. The actuation of the pistons 71 in the reverse direction is accomplished with the deenergization of the solenoid valve 69 whereupon the pressurized fluid flows in the line 72 while 70 is opened to the reservoir 55 which for simplicity has additionally been depicted as reservoirs 55a and 55b. Thus, the fluid residing in the hydraulic lift cylinders 52 is returned to the reservoir 55 through either line 70 or 72 in accordance with the position of the four-way solenoid valve 69. The line 62 supplies pressurized fluid to the four-way solenoid valve 73 which in turn directs the fluid flow into the lines 74 or 75 depending upon the position of the valve while the fluid is residing in the cylinder 53 is returned to the reservoir through the unpressurized line. Cylinder 54 is actuated by pressurized fluid entering the four-way solenoid valve 76 by means of the line 63 with the particular direction of travel thereof dependent upon whether the line 77 or line 78 is pressurized. The fluid return is directed into the reservoir 55.

#### ELEVATOR SYSTEM

The mandrel elevator system 80, as best shown in FIGS. 2 and 11, is adapted to raise and lower the mandrel 81 in accordance with a desired weaving pattern so that the rate at which the mandrel is raised or lowered is synchronized with the rate of weaving.



An electric motor 82 is connected to the drive shaft 166 and the right angle gear reducer 85 by means of couplings 83 and 84, respectively. The drive shaft 166 is connected to the weaving mechanism which will be hereinafter described. The right angle gear reducer 85 is connected to the chain and sprocket arrangement 87 by means of the electric clutch 86. One end of the chain and sprocket arrangement 87 is connected to the sprocket 88 which is mounted on the shaft 89 of the worm and worm gear housing 92. Additionally there is provided the electric clutch 90 connecting the shaft 89 to the variable speed direct current right angle drive motor 96. The worm gear housing has the worm 94 extending therethrough with the enclosure 95 submerged below the first level to accommodate the worm when in the fully retracted position. The electric clutches 86 and 90 are electrically interlocked whereby only one of them can be energized at a given time. Thus, when the clutch 86 is energized the motor 82 only is adapted to raise or lower the mandrel 81 by means of the worm 94 at a speed corresponding to the weaving rate. When the electric clutch 90 is energized the clutch 86 is deenergized and the auxiliary drive motor 96 is adapted to raise or lower the mandrel 81 at a substantially higher rate of speed than the weaving rate. Thus, the auxiliary drive motor 96 provides for the rapid positioning of the mandrel 81 along the vertical axis of the apparatus.

#### WARP YARN SUPPLY

Warp yarn is supplied for weaving by the apparatus of this invention by a plurality of creels 100 which are spaced radially with respect to and substantially equidistantly about the vertical axis of the apparatus, the arrangement of the creels being shown in FIG. 1. It is desirable for creels 100 to be suspended from concentrically arranged rails (not shown) so that they may be moved to permit access into the interior portions of the apparatus from any location. Each creel is provided with a plurality of spools as shown in FIGS. 30 and 31.

The creel frame 101 is comprised essentially of upright and horizontal members 102 and 103, respectively, and bracing members (not shown) which provide the desired rigidity. A spool station 104 includes a substantially horizontally positioned shaft 115 which is cantilevered from an upright member 102. Each shaft 115 is adapted to receive a plurality of spools 105, as shown in FIG. 31. Each spool 105 includes a cylindrical bore 106 which adapts the spool to be rotatably mounted on shaft 115. Spool 105 further includes a cylindrical opening 107 which is larger than and concentric with bore 106 and which receives a torsion spring 108. Shaft 115 is provided with an axially aligned flat surface 110 which extends the length of the same and which is adapted to receive the short length 111 of torsion spring 108. Torsion spring 108 is wound inside of cylindrical opening 107 in the direction such that when warp yarn 114 is withdrawn spring 108 is urged into further compression. Portion 112 of torsion spring 108 frictionally engages the cylindrical wall which defines the cylindrical opening 107. Thus, with the interior portions of spring 108 being prevented from turning upon the rotation of spool 105 by flat portion 111, yarn 114 is unwound from spool 105 under tension produced by the compression of spring 108 and by the frictional drag between portion 112 of spring 108 and the cylindrical wall of cylindrical opening 107.

Further, since spring 108 is coiled to a desired degree upon the rotation of spool 105, a sudden slackening in tension due to the motion of the heddles will result in the rewinding of the yarn 114. Therefore, it can be seen that a substantially constant tension is maintained on yarn 114 by means of torsion spring 108. The tension produced on warp yarn 114 as it is withdrawn from spool 105 may be varied in accordance with the length and rigidity of the spring 108 and the length of portion 112.

In reference to FIG. 2, the warp yarns 114 are drawn from their respective spools and through eyeboards 116 which are mounted in the weaving plane and which are supported by rigid members 118 and 119 substantially concentrically about the vertical axis of the apparatus. Rigid member 118 is connected to the third level 13 while rigid member 119 is connected to second level 14. Eyeboards 116 are provided with a plurality of small openings of which receives a warp yarn from a creel and aligns the yarn with the heddles.

#### MANDREL GUIDE

The mandrel guide 120 which is best shown in FIGS. 1, 2 and 3 comprises a plurality of vertically positioned rods 123 which are mounted to the fourth level 12 and third level 13. As shown in FIG. 3, five of such rods 123 are substantially equidistantly spaced around the vertical axis of the apparatus and provide the vertical tract 121 along which spider guide 122 moves. Each of the arms 124 of the spider guide 122 at the outward extremity thereof receives a pair of concave rotatable rollers 125 which adapts the spider guide 122 to be aligned with the length of track 121. The spider guide 122 is provided with a bore 126 which is concentrically arranged therein and which has an axis being common with the vertical axis of the apparatus. The bore 126 is adapted to receive shaft 127. The shaft 127 is pinned to the spider guide 122 by means of the pin 721. It can be seen that almost perfect vertical alignment can be achieved by use of spider guide 122 and tract 121; however, while five rods 123 are shown in FIG. 3, substantially good vertical alignment can be achieved by the use of either less or more of such rods and a corresponding number of arms 124 on the spider guide 122.

#### CONCENTRIC RINGS FOR ADDITION OF WARP YARNS

The mandrel as shown in FIG. 2 is of the type which has an increasing diameter throughout the length thereof to provide a substantially conically-shaped structure. To maintain uniform density of filaments within the woven fabric produced on such a mandrel configuration, warp yarns must be added to the fabric during weaving to compensate for the increase in the diameter of the mandrel as weaving progresses there along. Warp yarns may be included in the general weaving plane but maintained in the upper portion of the shed until they are programmed to be woven into the fabric; however, it is desirable to incorporate such warp yarns in the shed only when needed in order to save quantities of yarn which would otherwise be wasted since the length of the yarn from the top of the mandrel to the point at which it is first woven into the fabric would be cut away. FIGS. 6, 7, 8 and 9 show a

plurality of concentric rings and support devices which are adapted to provide extra warp yarns to the weaving shed when needed.

The annular ring member 130 is substantially concentrically positioned with the vertical axis of the apparatus and is secured to the bottom of the vertical rods 123 by any convenient means. Annular ring member 130 has mounted thereon a plurality of solenoid actuated ring supports 131. The ring supports 131 include a solenoid 132 which is anchored to annular ring member 130, a retractable plunger 133 which is adapted upon actuation by solenoid 132 to be withdrawn into the same a given distance, a ring support 135 which is connected to shaft 133 and which is adapted to slide on annular member 130, a compression spring 136 which is positioned between solenoid 132 and support 135 for normally maintaining support 135 in an outward position and for returning support 135 to that position after actuation, and a limit stake 137 which defines the outward movement of support 135. The solenoid actuated ring supports 131 are selectively positioned about the upper surface of annular ring member 130 and are adapted to receive arms 138 of concentric ring members 139. Each concentric ring member 139 is provided with three radially extending arms 138 and each of the arms 138 is adapted to be positioned on either a support 135 or rest directly on annular ring member 130. Thus, three solenoid actuated ring supports receive and support one concentric ring member 139 by means of arms 138. As it is desired for a particular concentric ring member to drop into position upon the annular ring member 130, the three solenoid actuated ring supports 131 are simultaneously energized with the ring support 135 being retracted by means of retractable plunger 133 thus clearing the end of arms 138 and allowing the arms to fall to a resting position on annular ring member 130. Upon the dropping of concentric ring member 139 onto annular ring member 130, the warp yarns laced under the lower edge and connected to the concentric ring member 139 are positioned to be incorporated into the weaving shed. The warp yarns connected to the concentric ring member 139 are placed symmetrically around the circumference thereof. The number of warp yarns connected thereto is dependent upon the total number of warp yarns to be added into the fabric and the number of concentric rings. As shown in FIG. 7, the concentric ring members 139 drop into position to enable the selective weaving of the warp yarns connected thereto into the fabric. The concentric ring subsequently rests upon the surface of the fabric and is raised therewith as weaving progresses. Warp yarns may be connected only to an arc of the periphery of the concentric ring member 139 where the mandrel has an exterior contour which provides for only a portion of the periphery to be expanded downwardly along the axis thereof; thus, the warp yarns are connected to the concentric rings only in the area of enlargement.

Upon the starting of the apparatus, the warp yarns initially to be woven into the fabric at the top of the mandrel may either be secured to the mandrel or may be secured to a concentric ring which has a reference numeral 140. Since concentric ring 140 does not need to be dropped downwardly and into the position of the weaving plane, the corresponding solenoid actuated

ring supports 131 are not needed and the arm of concentric ring 140 may rest directly upon annular member 130. If a concentric ring 140 is not to be employed, the warp yarns may be attached to the top of the mandrel by any convenient means such as suitable adhesive tape, an appropriate glue, a clamping device or the like.

#### FILLING YARN INSERTER DRIVE MECHANISM

In reference to FIGS. 2, 11 and 12, second level 14 has extending upwardly therefrom a plurality of support rods 150 which are substantially equidistantly spaced about the vertical axis of the apparatus and which support the main drive gear support 152. The main drive gear support 152 is provided with a plurality of concentrically arranged grooves 153 which are adapted to receive the bearing balls 154 which comprise in alternating sequence hardened steel balls and non-metallic spacer balls. The plurality of balls 154 rollably receive the main drive gear 155 which is annular in shape and which is adapted for rotation about the vertical axis of the apparatus by means of the balls 154 and grooves 153. The main drive gear support 152 has secured thereto a plurality of vertical gear supports 157, the gear supports 157 being affixed thereto by means of the screws 158 or the like. The gear supports 157 are spaced substantially equidistantly about the periphery of the main drive gear support 152 and are adapted to accommodate a gear shaft 160. Additionally the vertical gear supports are provided with the throughbore 716 to accommodate the drive shaft 166 and the plurality of brake shafts 717.

Each of the gear supports 157 is provided with a bore 161 supporting therein the plain bearings 162 and 163 for rotatably mounting the shaft 160 and the gears 164 and 165 which are affixed to the ends thereof as by pinning or the like.

The main drive gear 155 is rotated about its axis by means of the shaft 166 (FIG. 2) which is connected directly to a given gear shaft 160 and which is further connected to the drive gear motor 82 by means of the coupling 83. While several of the gear shafts 160 may likewise be driven by drive shaft 166, it is necessary only to drive one of such gear shafts since the rotation of that gear shaft drives the main drive gear 155 which in turn rotates the remainder of the gear shafts 160 by means of the meshing engagement between the main drive gear 155 and the gears 165. Thus, it can be seen that as the gear 165 is rotated by its engagement with the main drive gear 155, the gear 164 is also rotated in the same direction since the gears 164 and 165 are mounted on a common shaft.

Each of the gear supports 157 is provided with a filling yarn inserter support rail segment 170 which is adapted to receive the filling yarn inserters as they are driven circumferentially about the vertical axis of the apparatus by means of the gears 164 engaging a rack segment associated with the filling yarn inserter.

The drive shaft 166 and the plurality of shafts 717 (FIGS. 2 and 11) have connected thereto the respective electromagnetic brakes 636, 637, 638, 639 and 640. The plurality of brakes are supported from the second level 14 by means of the brackets 718.



## FILLING YARN INSERTERS

The filling yarn inserter 180 as generally set forth in FIGS. 14, 15, 16, 17, 18 and 19 is adapted to supply the filling yarn 184 at the rate of a single pick per filling yarn inserter per revolution of the main drive gear 155 for the weaving of the thick-walled, integrally woven, selvage free, three-dimensionally shaped fabric of this invention and to deliver the yarn 184 to substantially the precise point of incorporation into the fabric at a preselected level of filling yarn tension.

To facilitate the delivery of the yarn 184 to substantially the precise position in the shed for final incorporation into the fabric weave the filling yarn tip 181 is adapted to move inwardly and outwardly in a plane substantially perpendicular to the vertical axis of the apparatus as the filling yarn inserter 180 is propelled around the same axis along a substantially circular path in the same plane. The tip 181 moves in and out a distance substantially equal to the thickness of the fabric being woven divided by the number of filling yarn inserters employed. The oscillatory motion of the tip 181 directly associated with laying the yarn 184 in the shed at the proper depth for incorporation into the weave will hereinafter be referred to as the weaving oscillating motion. The tip 181 is also adapted to move inwardly and outwardly in a non-oscillating manner in order to compensate for non-circular cross-sections of the mandrel 81 and/or variations in mandrel cross-sectional area as weaving progresses. The motion of the tip 181 associated with following the contour of the mandrel, i.e., the periphery or point generatrix of the cross section of the mandrel 81 at the plane of weaving, and independent of the weaving oscillating motion will be hereinafter referred to as the mandrel tracking motion.

The filling yarn inserter 180 includes a tip 181 which is slidably mounted by means of a dove tail arrangement or the like in the tip carrier 182. The tip 181 includes an opening 183 which is adapted to receive and to permit the travel of the filling yarn 184 therethrough thereby inserting the filling yarn into the shed which is formed of the warp yarns. The outwardly extending end of the tip carrier 182 is provided with a shed spreader 185 which assists in spreading the shed sufficiently to allow the filling yarn inserter to pass therethrough. Likewise and for the same purpose the ends of intermediate carrier 191 are provided with shed spreaders 707 and 708. The tip 181 is adapted to slide in the channel 186 of the tip carrier 182 by means of sprockets 187 and 189 and the chain 188. The sprocket 187 is mounted at the forward end of tip carrier 182 and sprocket 189 is mounted at the rearward end thereof with chain 188 tautly held therebetween to form a closed path. The pin 190 extends through the chain 188 and securely fastens the same to the tip 181. The tip carrier 182 is slidably mounted in track 193 which is defined by the intermediate carrier 191. The chain 188 is provided with another pin 192 which extends through same and securely attaches the chain 188 to the intermediate carrier 191. Thus, as the intermediate carrier 191 moves outwardly, pin 192 forces the chain 188 to move about its endless path around the sprockets 189 and 187 to cause the tip 181 to move outwardly due to its attachment to the pin 190. The intermediate carrier 191 is also provided with the sprockets 194 and 195 about which the chain 196

moves in an endless path. The chain 196 is provided with the pin 197 which extends through same and into the tip carrier 182 and the pin 198 which extends through the chain 196 into the guide 201 of the base carrier 199. The base carrier 199 is provided with a pair of opposed and facing L-shaped guides 201 and 202 which define a track along which this intermediate carrier 191 slides. Guides 201 and 202 are secured to the base carrier 199 by means of screws 203 or the like. Thus, as the intermediate carrier 191 moves inwardly and outwardly along a path defined by the guides 201 and 202, tip carrier 182 moves inwardly and outwardly along track 193 of intermediate carrier 191 and tip 181 moves inwardly and outwardly along channel 186 of tip carrier 182. Due to the relationship of the tip 181 to the base carrier 199 through the telescoping carrier members 182 and 191 and their means of interconnections by way of the chains, sprockets, and pins 188, 196, 187, 189, 194, 195, 190, 192, 197, and 198 the extent of movement of the tip 181 with respect to the base carrier 199 is 3 times that of the power block 210.

Filling yarn inserter 180 is driven along a circular path by the gears 164 engaging the rack 719 which is secured to the rearward end of the base carrier 199 by screws or any appropriate means. Gears 164 are spaced around the axis of the apparatus at such intervals that rack 719 is engaged with at least one gear at all times. The tracking guide 213 which is fastened to the rack 719 by screws or any other appropriate means is supplied with a tracking guide slot 720 which engages at all times at least one segmented rail 170 which functions to precisely guide the filling yarn inserter tip 181.

The filling yarn inserter 180 is slidably supported at the outboard end of the base carrier 199 by filling yarn inserter support members 713 having a low coefficient of friction. The support members 713 are mounted on a filling yarn inserter support ring 714 which is substantially concentric with the main drive gear 155 and supported by cantilevered brackets 715 which are secured to the gear supports 157.

The support members 713 are mounted in a circle concentric with the apparatus and spaced sufficiently close together that a base carrier 199 is always in contact with at least one support member 713.

The tip 181 is moved inwardly and outwardly by means of the chain and sprocket arrangement as previously described and by means of the star wheel 205, flexible drive cable 206, meshing gears 207 and 208, threaded shaft 209 and threaded power block 210. The star wheel 205 is rotatably mounted in the upper portion of the tracking guide 213 which slides on yarn filling inserter support rail segments 170 and is directly connected to the flexible drive shaft 206 so that upon the rotation of the star wheel 205, a likewise rotation is produced in the flexible drive shaft 206. The rotation of the star wheel 205 is effected by elements shown in FIG. 12 wherein a gear support 157 has mounted thereto the filling yarn inserter index support bracket 171 which extends over the support rail segment 170. The index support bracket 171 includes the two horizontally positioned bores 173 and 174 which respectively receive the solenoid actuated and spring loaded pins 175 and 176. The solenoid actuated pins 175 and 176 are pushed inwardly against their respective springs 711 and 712 by the pivoting motion of the

bars 178 and 179, respectively. The bars 178 and 179 are pivotally mounted by means of the pivot pin 225. The bars 178 and 179 are in turn connected to the respective solenoids 704 and 618 by means of the flexible wires 705 and 706. The electrical energization of the solenoid 704 actuates the bar 178 to force the pin 175 into engagement with the star wheel 205 which results in rotating of the star wheel 205 one quarter of a revolution in the clockwise direction as the filling yarn inserter 180 moves in the direction as indicated in FIG. 19. The star wheel 205 is caused to rotate in the counter clockwise direction by the energization of the solenoid 618 and the simultaneous actuation of the pin 176 which engages the star wheel as depicted in FIG. 19. The solenoids 618 and 704 function to control the mandrel tracking motion of the filling yarn tip 181.

The solenoids 704 and 618 are electrically interlocked to prevent the actuation of pins 175 and 176 simultaneously and thus the pins 175 and 176 are programmed to selectively engage the star wheel 205 to rotate the same in either a clockwise or counter clockwise direction. In a similar manner the weaving oscillating motion is controlled by an identical but separate assembly comprising solenoids 214 and 215, connecting flexible wires 211 and 212, and pivot bars 178 and 179 (identical to those previously described). Also included are identical spring loaded pins 175 and 176 and springs 711 and 712.

The star wheel 205 is prevented from rotating more than one quarter of a revolution in either direction by means of the detent spring arrangement 216. The detent spring arrangement 216 includes a slide bar 217 having elongated slots 218 and 219 for slidably mounting with aligning pins 220 and 221. The slide bar 217 has an abutting end 222 which normally resides against a flat portion of the star wheel 205 and is maintained in that position by means of the detent spring 223 which is connected between pin 220 and end 224 of slide bar 217. As the star wheel 205 rotates by engaging either of spring loaded pins 175 or 176, slide 217 moves in the direction opposite to that of the arrow in FIG. 19 thus elongating the spring 223 which in turn provides the necessary force to return the slide bar 217 to its normal resting position against a flat surface of the star wheel 205 upon the completion of the quarter revolution of the star wheel 205.

The base carrier 199 of filling yarn inserter 180 is provided with a spool 228 which is rotatably mounted upon vertically arranged shaft 229, the vertical shaft 229 being rigidly secured to base carrier 199. Spool 228 supplies yarn 184 for distribution to tip 181 and ultimate insertion into the woven fabric as filling yarn. The yarn 184 is pulled from spool 228 around guide 230 and through tensioning means 231. The tensioning means 231 is of the adjustable type and the tension applied to the yarn may be increased or decreased by the selective rotation of nut 232. The yarn 184 then passes around a second guide 233, through stop mechanism 234, around a third guide 235, around aligning guide 237, through support plate 236 and into tip 181. The yarn 184 is pulled through opening 183 in tip 181 and is incorporated into the fabric at that point.

In reference to FIG. 18, the yarn break detector 234 includes a U-shaped yarn guide 238 which is mounted

on base carrier 199 in an upwardly extending position. A magnet 239 and a support arm 243 are mounted to the pivot support 240 by means of the pivot arm 241 and the screw 242. Under normal conditions, support arm 243 rests between the upright arms of the U-shaped yarn guide 238 and is supported by yarn 184 which extends through the eyelets 247 and 248 in the U-shaped yarn guide 238. Yarn 184 in turn supports the magnet 239 in a pivotally raised position. Upon the breaking of yarn 184, the magnet 239 pivots downwardly under the influence of gravity so that it resides in opening 245 of base carrier 199 as shown in dotted lines in FIG. 18. The filling yarn inserter 180 continues to move along its normal path until the magnet 239 comes in close proximity to a reed switch (hereinafter described) which closes an electrical circuit whereby the weaving apparatus is substantially instantaneously stopped from further rotation.

FIG. 15 shows the filling yarn inserter 180 in a completely retracted position. The tip 181 is extended by solenoid 704 being energized which pushes the spring loaded pin 175 into contact with the star wheel 205 to turn same in a clockwise direction. The clockwise rotation of the star wheel 205 of one quarter of a revolution causes likewise a clockwise rotation in gear 207 which in turn by meshing engagement with gear 208 rotates the same in a counterclockwise direction. A counter-clockwise rotation of gear 208 results in the threaded power block 210 being driven outwardly along the threaded shaft 209 whereby the intermediate carrier 191 is driven outwardly along the track provided by the base carrier 199 in combination with the guides 201 and 202. As the intermediate carrier 191 moves outwardly the chain and sprocket arrangement 194, 195 and 196 causes tip carrier 182 to likewise be moved outwardly along the track of the intermediate carrier 191 which in turn actuates the chain and sprocket arrangement 187, 188 and 189 to result in the movement outwardly of the tip 181 a distance equal to three-fourths the lead of the threaded shaft 209.

#### FABRIC COMPACTOR

A fabric compactor 250 is generally shown in FIGS. 21, 22 and 23. As shown in FIG. 10, four fabric compactors 250 are depicted as it is generally desirable to have the same number of fabric compactors as there are filling yarn inserters. However, fewer fabric compactors than filling yarn inserters may be employed and, depending upon the configuration of the desired fabric, as for example the conically woven fabric depicted in FIG. 2, the fabric compactors may be dispensed with since the relationship of the tension of the yarns in combination with the mandrel shape and the direction along the mandrel surface at which weaving is effected provides a very compactly woven fabric. Additionally weaving may be accomplished in the absence of any compactors if a loosely woven fabric is required.

The fabric compactor 250 is provided with telescopic motion whereby it is adapted to follow the contour of substantially any mandrel configuration and is mounted securely to the main drive gear 155 by means of the plurality of screws 254. Thus, the compactor 250 moves in a circular orbit about the vertical axis of the apparatus with the movement of the main drive gear



155. The fabric compactor 250 is comprised of an impactor slide 251 which in turn is slidably mounted to the slide carrier 253. The intermediate slide 252 is provided with a grooved channel 255 which is adapted to slidably receive the impactor slide 251 by means of the plurality of balls 256 to provide for substantially frictionless movement thereof. The intermediate slide 252 is likewise slidably mounted to the slide carrier 253 by means of the grooved channel 257, the plurality of balls 258 and the positionable gib 269 which is provided to enable adjusting the clearance of the balls with the channel 257 grooves. The gib 269 is securely fixed to the base carrier 253 by means of screws 279.

The impactor slide 251 is provided with the upwardly extending arm 259 which mounts for rotation the bladed impactor 260 by means of the cam roller bearing shaft 261. As shown in FIG. 12, the bladed impactor 260 resides beneath the as woven fabric and exerts an upward force thereupon whereby the yarns are compacted into the fabric to increase the density thereof. The surface 262 of the bladed impactor 260 is provided with a smooth surface since it maintains rubbing contact with the mandrel surface during weaving.

The telescopic motion of the intermediate slide 252 in the extended direction is effected by means of the spring loaded reel 249. The reel 249 is comprised of a spool 263, a recoil spring (not shown) and a flexible wire cable 264 which is wound about the spool 263. The spool 263 is mounted for rotation by means of the vertical shaft 277 which is affixed to the reel base plate 265. The base plate 265 is affixed to the slide carrier 253. The flexible wire cable 264 is withdrawn from the spool 263 under tension and is passed through the guide 266 and around the pulley 267 which is mounted for rotation by means of shaft 268 affixed to the movable gib 269 of the slide carrier 253. The end of the wire cable 264 is securely connected to the intermediate slide 252 by means of the threaded post 278.

The impactor slide 251 is simultaneously actuated in the extending direction with the intermediate slide 252 by means of the sprockets 270 and 271 and the chain 272. The sprockets 270 and 271 are respectively mounted for rotation by means of shafts 273 and 274 which in turn are mounted to the intermediate slide 252. The chain 272 is secured by means of the pins 275 and 276 to the carrier slide 253 and the impactor slide 251 respectively whereby the motion of the intermediate slide 252 by the tensioned wire cable 264 is translated to the impactor slide 251 through the motion of the chain 272.

The fabric compactor 250 is adapted for retraction by providing a slightly greater force at the impactor 260 then is provided by the spring loaded reel 249. Thus the fabric compactor 250 will maintain contact with and follow the contour of a mandrel having a substantially continuously increasing or decreasing diameter.

To provide a degree of rigidity to a plurality of fabric compactors 250 the support ring 246 is securely fastened to each compactor and moves therewith about the vertical axis of the apparatus.

The utilization of less than two fabric compactors during weaving would obviate the use of the support ring 246.

## FIRST FABRIC EMBODIMENT

FIGS. 38-62 illustrate the segmented insertion of filling yarn in the weaving of a given fabric with the utilization of four filling yarn inserters 180. The fabric 280 comprises a plurality of locker warp yarns 281, a plurality of filling yarns 282, and a plurality of stuffer warp yarns 283.

Each horizontal row of filling yarns 282 will hereinafter be called a deck while each vertical row of filling yarns will be called a course which is not to be confused with the definition of a "course" in knitting. For a given fabric, the number of filling yarns forming a deck is dependent upon the required fabric thickness. For example, the embodiment shown in FIGS. 38-62 has 12 filling yarns per deck. The number of filling yarns forming a course will vary with the length of the fabric. The number of stuffer warp yarns across a given deck will vary with the thickness of the fabric and will be one less than the number of filling yarns, i.e., eleven stuffer yarns are employed in the embodiment depicted in FIGS. 38-62. For purposes of illustration, the courses of filling yarns are numbered 284, 285, 286, 287, 288, 289, 290, 291, 292, 293, 294, and 295.

The number of courses which may be woven into a given fabric is dependent upon the number of filling yarn inserters utilized in the weaving thereof. That is, the number of courses of which a given fabric may be comprised must be a whole number multiple of the number of filling yarn inserters employed in the weaving thereof. For example, if two filling yarn inserters were to be employed to weave the fabric of FIGS. 38-62, the first filling yarn inserter would be programmed to weave courses 284 through 289 and the second filling yarn inserter would be programmed to weave courses 290-295. Whenever more than one filling yarn inserter is employed each will be programmed to weave adjacent courses to prove an ordered yarn fabric.

In the instant example, the four filling yarn inserters are numbered 180a, 180b, 180c, 180d with filling yarn inserter 180a supplying filling yarn to courses 284, 285, and 286; the filling yarn inserter 180b supplying filling yarn to courses 287, 288, and 289; the filling yarn inserter 180c supplying filling yarn to courses 290, 291 and 292; and the filling yarn inserter 180d supplying filling yarn to courses 293, 294, and 295.

In reference to FIG. 38, deck 296 has been completed by the insertion of filling yarn 297 which is the last of such yarn to be placed in deck 296 for that particular sequence. It can be seen that locking warp yarns 298 and stuffer warp yarns 299 and 300 form the upper portion of the shed while stuffer warp yarns 301, 302, 303, 304, 305, 306, 307, 308, 309 and locking warp yarns 310 form the bottom portion of the shed. To prepare for the formation of deck 311, the shed is changed by the Jacquard heads so that stuffer warp yarns 299 through 309 and locker warp yarn 310 form the upper portion of the shed while locker warp yarn 298 forms the bottom portion of the shed. In FIG. 39, filling yarn 312 which is carried by filling yarn inserter 180a is carried through the shed formed as described immediately above and pulls locker warp yarn 298 inwardly until the same rests against the mandrel 81. Since filling yarn inserter 180a is immediately followed

by filling yarn inserter 180b, the shed is changed by the Jacquard head (as shown in FIG. 40) so that the stuffer warp yarns 299 through 306 and the locker warp yarn 310 form the upper portion of the shed while stuffer warp yarns 307, 308 and 309 and locker warp yarns 298 forms the lower portion of the shed. In FIG. 40, filling yarn 313 is laid in the course 287 and remains there since stuffer warp yarn 307 prevents filling yarn 313 from being drawn closer to the mandrel 81 and filling yarn 313 is thereafter held in that position by the tension induced by filling yarn inserter 180b.

In FIG. 41, the filling yarn 314 is placed in course 290 by filling yarn inserter 180c. The upper portion of the shed is formed by the stuffer warp yarn 299 through 303 and locking warp yarn 310 while the lower portion of the shed is formed by stuffer warp yarn 304 through 309 and locker warp yarn 298. The shed as programmed by the Jacquard heads and as shown in FIG. 42 has its upper portion comprised of the stuffer warp yarns 299 and 300 and the locker warp yarns 310 and the lower portion of the shed is formed by stuffer warp yarns 301 through 309 and locker warp yarn 298. Filling yarn 315 is placed into course 293 by the filling yarn inserter 180d. It can now be seen that each of the filling yarn inserters 180 has made one complete revolution and; therefore, prior to insertion of the next series of filling yarns, each of the filling yarn inserter star wheels 205 engages solenoid actuated pin 176 and is turned one quarter of one revolution so that tip 181 is moved outwardly and away from the mandrel 81, a distance which is substantially equal to the distance between the courses.

In FIG. 43, filling yarn 316 is directed into course 285 by the shed which has its upper portion formed of stuffer warp yarns 299 through 308 and locker warp yarn 310 and the lower portion formed of stuffer warp yarns 309 and locker warp yarns 298. Filling yarn 316 is carried by filling yarn inserter 180a and in effect is a continuation of filling yarn 312.

In FIG. 44, the upper portion of the shed is comprised of the locker warp yarns 310 and stuffer warp yarn 299 through 305 and the lower portion of the shed is comprised of the locker warp yarn 298 and stuffer warp yarns 306 through 309. Filling yarn 317 is inserted in course 288 by filling yarn inserter 180b, filling yarn 317 being a continuation of filling yarn 313. In FIG. 45, the shed has its upper portion comprised of the stuffer warp yarns 299 through 302 and the locker warp yarn 310 has the lower portion of the shed comprised of the stuffer warp yarns 303 through 309 and the locker warp yarn 298. Filling yarn 318 is laid into course 291 by the filling yarn inserter 180c as a continuation of filling yarn 314. In FIG. 46, the shed has its upper portion formed of locker warp yarn 310 and stuffer warp yarn 299. Filling yarn 319 is laid into course 294 by filling yarn inserter 180d and is a continuation of filling yarn 315. It can be seen that the filling yarn inserters 180 have made a second revolution and each has laid its yarn in the selected course.

The filling yarn deck 311 is completed by a third revolution of each of the filling yarn inserters 180; the beginning of which is shown in FIG. 47, wherein the upper portion of the shed is comprised of the stuffer warp yarns 299 through 307 and locker warp yarn 310 while the lower portion of its shed is comprised of the

stuffer warp yarns 308 and 309 and locker warp yarn 298, the filling yarn 320 is inserted into course 286 by filling yarn inserter 180a and is a continuation of filling yarn 316. In FIG. 48, the shed has the upper portion thereof formed by stuffer warp yarns 299 through 304 and locker warp yarn 310 and has the lower portion thereof comprised of the stuffer warp yarns 305 through 309 and the locker warp yarns 298. Filling yarn 321 is laid into course 289 by means of the filling yarn inserter 180b with filling yarn 321 a continuation of filling yarn 317. In FIG. 49, the shed has its upper portion formed from stuffer warp yarns 299, 300 and 301 and locker warp yarn 310. The filling yarn 322 is inserted into course 292 by the filling yarn inserter 180c, filling yarn 322 being a continuation of filling yarn 318. In FIG. 50, deck 311 is completed. The shed therein has its upper portion formed by locker warp yarn 310 and has the lower portion of its shed formed by the locker warp yarns 298 and stuffer warp yarns 299 through 309. Filling yarn 323 is inserted into course 295 by means of the filling yarn inserter 180d.

In FIG. 51, the filling yarn deck 324 is begun by the filling yarn inserter 180a inserting the filling yarn 325 into the course 286 with the lower portions of the shed comprising the locker warp yarns 310 and the stuffer warp yarns 308 and 309. During the insertion of the filling yarn 325 into course 286 the tip of the filling yarn inserter 180a has forced the locker warp yarns 310 toward the mandrel surface. The filling yarn 325 is a continuation of the filling yarn 320 and is seen to reside in the same course 286.

Since both the filling yarns 320 and 325 are inserted by the same filling yarn inserter upon successive revolutions thereof it should be apparent that the filling yarn inserters 180a, 180b, 180c and 180d are programmed such that the tips thereof are neither retracted or extended between the completion of the weaving of one deck of filling yarns and the starting of the next successive deck. The latter mode of programming the retraction and extension of the filling yarn tips is utilized regardless of the weave pattern or the number of filling yarn inserters being employed to maintain an ordered fabric weave.

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

In FIG. 52, the shed is formed substantially like the shed shown in FIG. 47 with the filling yarn 326 being laid into the course 289 by means of the filling yarn inserter 180b. The filling yarn 326 remains in course 289 even though under tension, for stuffer warp yarns 305 prevent the same from moving toward the mandrel 81. In FIGS. 53 and 54, the sheds are formed as previously depicted in FIGS. 48 and 49 with filling yarns 327 and 328 respectively laid into courses 292 and 295 by means of filling yarn inserters 180c and 180d.

It may be seen that each of the filling yarn inserters 180 has made one complete revolution about the axis of the mandrel whereupon the star wheel 205 is rotated one quarter of one revolution in the opposite direction by engaging the solenoid actuated pin 176 so that tip 181 will be one course closer to the mandrel than on the previous rotation. In FIG. 55, the shed has its upper portion formed by the stuffer warp yarns 299 through 308 and locker warp yarns 298 and the bottom portion



formed by stuffer warp yarns 309 and the locker yarns 310. Filling yarn 329 which is a continuation of filling yarn 325 is passed through the shed and laid in the course 285 by filling yarn inserter 180a. Also viewing FIG. 51, it can be seen that the locker warp yarn 310 has its extremity moved inwardly from course 286 to 285 by means of the tip of the filling yarn inserter 180a. The filling yarn 329 is prevented from moving closer to the mandrel 81 and into course 284 by means of the stuffer warp yarns 309. In FIGS. 56, 57, and 58, the sheds for allowing filling yarn 330, 331 and 332 to be woven into the courses 288, 291 and 294 respectively by means of the filling yarn inserters 180b, 180c and 180d is much the same as has been described for the formation of the sheds for those particular courses.

Upon the formation of the shed as shown in FIG. 59, the star wheels 205 are rotated one quarter of one revolution by the actuating pin 176 thus moving tip 181 one course in the direction of the mandrel 81 so as to place the filling yarns in those courses which lack such yarns and upon the insertion of the same will complete the deck 324. The shed as shown in FIG. 59 has its upper portion comprised of all of the stuffer yarns and has its lower portion comprised only of the locking warp yarns 310. Thus, as filling yarn inserter 180a proceeds through the shed, the tension thereof draws the locker warp yarns 310 into a position adjacent the mandrel by placing filling yarn 333 in course 284. The filling yarn 333 is a continuation of the filling yarn 329. Thus, it can be seen that since the filling yarn inserter 180a only supplies such yarn to courses 284, 285, 286, all of the filling yarn in those courses are a continuation of each other. In FIGS. 60, 61 and 62, the filling yarns 334, 335 and 336 are respectively positioned into courses 287, 290 and 293 by means of filling yarn inserters 180b, 180c and 180d. The sheds are formed in essentially the same way as herein before set forth for the particular courses in question. Thus, upon the insertion of filling yarn 336, the complete cycle which includes filling yarn decks 311 and 324 is completed whereupon the procedure is repeated until the product is woven.

The FIGS. 38 through 62 show a fabric having a thickness of twelve filling yarns, eleven stuffer warp yarns and two locker warp yarns; however, this thickness may be varied over a space of several decks or from deck to deck if a contoured external surface of the woven product were required. This may be accomplished by providing sufficient additional stuffer warp yarns that are maintained external of the as woven fabric in the upper portion of the shed until such time as they are inserted into the weaving shed by the program of the Jacquard heads. Simultaneously with the insertion of the additional stuffer warp yarns into the weaving shed by the plurality of Jacquard heads the tips 181 of the yarn filling inserters 180 would be programmed to extend and retract over a greater number of courses in accordance with the number of stuffer warp yarns to be added. As previously discussed the number of stuffer warp yarns which are to be added or subtracted from the fabric during the weaving process must be a whole number multiple of the number of filling yarn inserters being utilized. In the example at hand the stuffer warp yarns would have to be added or subtracted in multiples of four since four filling yarn inserters are being employed to weave the fabric. Thus,

in the instant example, if the number of courses were to be increased from 12 to 16, the solenoid actuated pin which rotates the star wheel 205 at the end of the third complete revolution of the filling yarn inserters 180 would rotate the star wheel in the same direction for an additional one quarter of one revolution whereby each of the filling yarn inserters 180 would be programmed to extend and retract over the distance of four fabric courses during the weaving thereof.

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

## SECOND FABRIC EMBODIMENT

In FIGS. 63 through 71, a different pattern is depicted wherein the locker warp yarns as previously described are woven in a diagonal manner.

Filling yarns 352 are arranged in courses 340 through 351 and are separated both by locker warp yarns 353 and stuffer warp yarns 354. Depending upon the end use of the fabric, stuffer warp yarns 354 may or may not be incorporated into the fabric. The main purpose of such stuffer warp yarns 354 is to increase dimensional stability in the vertical direction. The particular pattern assumed by locker warp yarns 353 is controlled by the manipulation of the shed by means of the Jacquard heads, the pattern design being quite flexible and being limited only by the maintenance of such yarn in a given plane. For the embodiment shown, four filling yarn inserters 180 are used with filling yarn inserter 180a laying in filling yarn 352 for courses 340, 341 and 342, filling yarn inserter 180b laying in filling yarn 352 for courses 343, 344 and 345, filling yarn inserter 180c laying in filling yarn 352 for courses 346, 347 and 348 and filling yarn inserter 180d laying in filling yarn 352 for courses 349, 350 and 351. The sequence for laying in filling yarns 352 is substantially the same as has been previously described for the first revolution of the filling yarn inserters 180, filling yarn inserters 180a, 180b, 180c and 180d respectively lay in filling yarns 355, 356, 357 and 358 in courses 340, 343, 346, and 349. In order to preserve the diagonal pattern as set forth, locker warp yarn 359 immediately prior to and during the insertion of filling yarn 360 into course 341 by filling yarn inserter 180a is held in the lower part of the shed and therefore extends between filling yarn 360 and filling yarn 355. The second revolution of filling yarn inserters 180 respectively inserts filling yarns 360, 362, 363 and 364 into courses 341, 344, 347 and 350. Deck 365 is completed upon the completion of the third revolution of each of the filling yarn inserters 180a, 180b, 180c and 180d wherein filling yarns 352 are woven sequentially into courses 342, 345, 348 and 351. The immediately following deck is then sequentially woven into the fabric courses in the following order: 342, 345, 348, 351; 341, 344, 347, 350; 340, 343, 346 and 349. Upon the completion of the insertion of the filling yarn 352 into course 349, the sequence is ready to be repeated starting again with the weaving of the filling yarn 352 into course 340.

It can be seen that by eliminating the stuffer warp yarn 354, a thick-walled intricately woven three dimensionally shaped fabric may be woven with only two yarn

systems, those being filling yarns 352 and locker warp yarns 353.

#### ELECTRICAL CIRCUIT

The electrical circuit for powering and controlling the three-dimensional weaving apparatus of this invention is supplied alternating current from two separate sources, namely, 460 volt, three phase 60 cycle through lines 303, 304 and 305 and a 115 volt, single phase 60 cycle through lines 301 and 302, and double pole single through switch 311. The 460 volt supply is utilized to power the Jacquard heads hydraulic drive motor while the 115 volt supply provides power to the many control elements of the circuit. Additionally, two different voltages are obtained from the 115 volt source by rectification and voltage reduction which are respectively fed to a plurality of magnetically actuated relays which require a 24 volt, direct current supply and to stepping switches which utilize a 100 volt, direct current supply.

#### JACQUARD HEAD CONTROL CIRCUIT

Jacquard heads 16, 17, 18, 19 and 20, respectively, include 3 horsepower hydraulic drive motors 306, 307, 308, 309 and 310 which are connected to lines 303, 304 and 305 as shown in FIG. 72. The hydraulic drive motors are also connected to a common circuit breaker (not shown), and are remotely controlled by circuiting receiving power through switch 311 and lines 312 and 313. Each of the Jacquard hydraulic drive motors 306 through 310 are respectively connected to and are energized by magnetic motor starters 316 through 320 which in turn are remotely controlled by the plurality of pushbutton positions mounted on a control panel (not shown) and powered by the 115 V. AC. source by means of lines 312 and 313. The 115 volt power is employed to lessen the hazard to shock to the operator. The pushbutton positions respectively consist of the monetary contact "Start" pushbuttons 321, 322, 323, 324 and 325, the maintained contact "Stop" pushbuttons 326, 327, 328, 329, and 330 and the indicator lights 331, 332, 333, 334 and 335.

Since each of the hydraulic drive motors are identically connected to the control panel, only the circuit associated with hydraulic drive motor 306 will be described in detail. The maintained contact and momentary contact pushbuttons 326 and 321, respectively, are wired in series with the line 312, starter coil 336 and line 313 while starter holding contact 337 is wired in parallel therewith. Thus, when the hydraulic drive motor 306 is to be energized, the momentary contact pushbutton 321 is actuated to complete the circuit which energizes magnetic starter coil 336 and simultaneously therewith closes the starter holding contact 337. Contacts 338, 339 and 340 which connect motor 306 with lines 303, 304 and 305 are also simultaneously closed with the closing of starter holding contact 337, thereby energizing motor 306. The starter holding contact 337 maintains the circuit continuity until the circuit is broken by the actuation of maintained contact pushbutton 326.

#### ELECTRICAL CIRCUIT ASSOCIATED WITH HYDRAULIC SYSTEM

Jacquard heads 16 through 20 each include a hydraulic system, as has previously been described, and an electrical circuit associated with each hydraulic system for sequencing the various solenoid valves. As shown in FIG. 73, Jacquard heads 16 through 20 are controlled by a portion of the total circuit and since each portion of the circuit assigned to a particular Jacquard head functions identically with the other portions, only the electrical circuit associated with Jacquard head 16 will be described.

As shown in FIG. 36, the hydraulic system includes the four-way solenoid valves 69, 73 and 76 and the two-way solenoid by-pass valve 67. These valves are adapted for controlling the flow of the hydraulic fluid to the various hydraulic cylinders in the proper sequence. The magnetic coils of these valves derive their power from the 115 V. AC. source by means of power lines 350 and 351. Magnetic coil 353 is the coil of the four-way solenoid valve 73 and controls the actuation of the pattern card chain index and card reading control cylinder 53. Similarly, the magnetic coil 354 controls the actuation of four-way solenoid valve 76 which hydraulically controls the program card chain index control cylinder 54. Magnetic coil 355 is the coil of the four-way solenoid valve 69 which controls the actuation of the lift cylinders 52. The magnetic coil 356 which is the coil of the two-way solenoid by-pass valve 67 controls the fluid pressure in the hydraulic system below check valve 59 by the selective energization of the same.

The magnetic coil 353 is energized by the closing of limit switch 358 which is mounted on the Jacquard head frame in such a manner that the movement of a hook lifting knife 22 causes the switch to close. Upon the closing of the limit switch 358, power is supplied to magnetic coil 353 by line 359 which is connected to incoming line 350. Magnetic coil 356 which receives power from line 359 is energized by the closing of the single pole-double throw, time delay relay 360 which is set to operate at a time corresponding to the time period required to repressurize the hydraulic system and accumulator 64.

The magnetic coils 354, 355 and 356 are interconnected to the contact 361 of the three pole-double throw, magnetic relay 362 and the contact 363, of a 20 pole, four position magnetic stepping switch 365. The latter switch is of the latching type and does not actuate until after its magnetic coil has been deenergized. The magnetic relay 362 and the stepping switch 365 have the contacts thereof interconnected to single pole-double throw, relay 366, the three pole-double throw, magnetic relay 367, relay 367 having contacts 368, 369 and 370 and to reed switches 371 and 372. Reed switches 371 and 372 are mounted by means of brackets to gear support 157 so as to be positioned in close proximity to the path of travel of the filling yarn inserters (see FIGS. 10 and 12). The magnetic relays 362, 366 are energized from the 24 V. DC. power source (hereinafter described) by means of lines 375 and 376.

In series with the magnetic coil of relay 367 and its holding contact 368 is the maintained contact pushbutton 377 which enables the relay coil to be manually deenergized if any Jacquard head has failed to index



properly. The reed switches 371 and 372 along with the remainder of the reed switches 680, 683, 688, 690, 666, 665, 668, and 667 are sequentially actuated by the permanent magnet 700 (shown in FIG. 18) which is housed in the body of each filling yarn inserter.

The indicator light 378 is wired in series with the contact 379 of magnetic stepping switch 365 and the contact 370 of the magnetic relay 367. These indicator lights are wired in parallel with the 115 V. AC. power line 351 and afford a visual means of detecting a "missed pick" by the respective Jacquard head with which it cooperates. A "missed pick" relates to the failure of a Jacquard head to index properly, i.e., the failure of a Jacquard head to change the shed by the manipulation of its warp yarns at the proper time, as for example, by the failure of the proper reed switch to close as the filling yarn inserter passes in proximity thereto.

Power, 100 volt DC, is supplied to the stepping switch 365 by means of the current limiting resistor 381 which is in series with the rectifying diode 382 and contacts 383 of the relay 362, the maintained contact 384 of the stepping switch 365 and parallel connected current limiting resistor 385. Capacitor 386 which is in the 115 V. AC. line 351 and the 100 V. DC. line functions as a filter capacitor to reduce the ripple of the rectified voltage.

#### FILLING YARN BREAK DETECTOR

The circular weaving apparatus of this invention is provided with the means to stop the weaving function within a maximum angle of rotation of 9° upon the breakage of any filling yarn being inserted into the fabric by the filling yarn inserters.

The filling yarn break detection circuit comprises a plurality of two pole-double throw magnetic relays 390 through 429, reed switches 430 through 469, and the indicator lights 510. The reed switches are respectively mounted on each of gear housings 157 (see FIG. 10) and in position to be energized by magnet 239 upon the breakage of the filling yarn being inserted into the shed by the filling yarn inserters. The magnetic coils of the plurality of relay 390 through 429 and the indicator lights are wired in parallel to provide visual indication of just where a filling yarn break has occurred. The plurality of relays 390 through 429 are wired in parallel between the 24 volt DC. power line 375 and line 511 which is connected to the DC. ground line 376 through the "reset" pushbuttons 512. The latter enables the relays to be deenergized and reset after a filling yarn break has been repaired. These plurality of relays have their uppermost contacts 470 through 509 wired in series between the 24 volt DC. power line 375 and the contact 369 of relay 367 by means of line 514 such that energization of any of these relays results in stopping the weaving operation by opening the lock-out circuit consisting of the relays 390 through 429, the relay 367, the relay 515 and the relay 516.

In FIG. 77 there is shown an alternative circuit for detecting filling yarn breaks and the subsequent stopping of the weaving process upon the breakage of a filling yarn until the break can be repaired.

The circuit comprises the plurality of reed switches 430 through 469, the double pole-double throw magnetic relays 725 through 729, the indicator lights 720

through 724 wired in parallel with the magnetic coils of the respective relays 725 through 729, and the relay reset pushbutton 512.

The circuit provides a magnetic relay for each of the shed sectors with the reed switches residing in the same area as the shed sector wired in parallel with each other and in series with the hold-in contact of the corresponding magnetic relay such that the making of any one of the reed switches associated with a given shed sector results in energizing the corresponding magnetic relay whereby the lock-out circuit is interrupted and the machine stopped until the particular filling yarn break is repaired and the magnetic relay is deenergized by the actuation of the pushbutton 512 whereupon the lock-out circuit is remade and weaving may resume.

This circuit provides stopping the machine in a maximum angle of rotation of 9° upon the breakage of a filling yarn and additionally indicates the shed sector in which the breakage occurred which also indicates the particular filling yarn inserter having the break since only one filling yarn inserter can occupy a shed sector at a time.

#### WARP YARN ADDITION CONTROL CIRCUIT

In the weaving of many geometrically shaped fabrics, excluding that of a cylinder, it becomes necessary to add warp yarns to the fabric as weaving progresses to maintain a constant density of filaments within the fabric. With the weaving apparatus of this invention, the addition of warp yarns is accomplished by providing a plurality of concentric ring members 139 supported by the plurality of ring supports 131. The solenoids 132, associated with the arms 138 of a ring member 139, must be energized simultaneously by a common electrical signal to enable the ring member to drop smoothly onto the annular ring 130. Therefore, the single pole-double throw magnetic relays 530 through 538 are provided which have normally open contacts interconnected to parallel wired magnetic coils 520 through 528, respectively. The single pole magnetic relays 530 through 538 are selectively closed by the nine pole-two position stepping switch 539 which has nine of its contacts on one position series connected to the magnetic coils of relays 530 through 538 and the nine contacts of the other position being series connected to the indicator lights 540 through 548. The stepping switch 539 functions similarly to the stepping switch 367 in that the switch does not step until after its magnetic coil has been deenergized.

Power is supplied to the circuitry of the warp yarn addition control elements by means of the double pole-double throw switch 554 (which is shown in the open position) and the 115 volt AC. power line connections 555 and 556.

The two pole-double throw magnetic relay 550 provides the control function for the energization of the magnetic coil of the stepping switch 539 and the magnetic coils of the relays 530 through 538. The energization of the relay 550 is accomplished by means of the ring drop counter 551 which is programmed to actuate the magnetic coils and to drop a ring after a particular number of decks of fabric have been woven. The nine position rotary switch 553 is provided to enable presetting the stopping of the weaving operation simultaneously with the actuation of any one of the warp

yarn addition rings. As shown in FIG. 75, rotary switch 553 is preset to stop the machine upon actuation of the first concentric ring member as the magnetic coil of the "lock-out" relay 515 will be energized simultaneously therewith.

The 100 volt DC. coil of the stepping switch 539 is supplied power from the 115 volt AC. source by means of connections 555 and 556, the current limiting resistor 557, the rectifying diode 558 and contact 559 of the magnetic relay 550. The plurality of magnetic solenoid coils 520 through 528 and the coils of the magnetic relays 530 through 538 operate from the 115 volt AC. power supplied by connections 555 and 556, and the contact 560 of the relay 550 wired in series with the plurality of parallel wired relays 530 through 538 and nine of the contacts of the stepping switch 539. The capacitor 561 functions to reduce the ripple of the rectified voltage. The momentary contact pushbutton switch 562 is provided to enable the coil of the stepping switch 539 to be energized so that a concentric ring member may be selected for subsequent dropping by the ring drop counter 237. The indicator lights 540 through 548 and the magnetic coils of the relay 550 and the lock-out relay 515 are powered by the 24 V. DC. source by means of connections 375 and 376.

#### 24 VOLT DC. POWER SUPPLY

The 24 volt DC. power supply for energizing the plurality of magnetic relays employing a 24 volt DC. coil consists of thyrector 570 connected across the 115 V. AC. lines 555 and 556. The thyrector suppresses voltage spikes on the powerline and thus functions as a diode protection means. In parallel with the thyrector 570 is the primary winding of the voltage reducing transformer 571 which is overload protected by the fuse 572. The secondary winding of the transformer 571 is connected to the rectifying bridge consisting of the rectifying diodes 572, 573, 574 and 575 which have their output connected in series to current limiting resistor 576, and in parallel to resistor 577 and capacitor 578. The 24 volt DC. output is wired to the plurality of relays through connections 375 and 376 with connection 376 functioning as the ground line.

#### FABRIC PROGRAMMING CONTROL CIRCUIT

In the weaving of a fabric having a shaped wall of considerable thickness, several machine elements must be programmed to function in accordance with the thickness of the fabric to be woven, the resultant geometric configuration of the finished product, the particular weave pattern being employed and the like. Specifically, filling yarn inserter tip 181 must be programmed to oscillate back and forth across the fabric thickness in order to deposit the filling yarn into the proper fabric course and radially with respect to the vertical axis of the apparatus to enable following a contoured mandrel surface. Further, the addition or subtraction of warp yarns from the shed and, resultingly, the fabric must be made in accordance with the contour of the mandrel and the desired shape of the finished fabric. The Jacquard cards 26, comprising the pattern card chain 25, in cooperation with the cards 33, comprising the program card chain 30, provide the program for positioning selected warp yarns in the upper and lower portion of the shed for the control of the

shed determines where the filling yarns are to reside within the woven fabric in accordance with a predetermined weave pattern. Additionally the program cards 33 control the sequential addition of the multiplicity of warp yarns associated with the rings and the ring drop control.

The above cited functions are programmed by means of three digit counters 580 and 581 and four digit counters 551 and 582 (model numbers 49600-401 and 49600-400, respectively, made by the Durant Manufacturing Company of Milwaukee, Wisconsin). These counters are wired in parallel with the 115 volt AC. power by means of lines 583 and 584. These counters register a single count with each revolution of the main drive gear 155 by means of the reed switch 586, being mounted on the main drive gear support 152, the permanent magnet 587 mounted on main drive gear 155 (see FIG. 10), and the four pole-double throw magnetic relay 588 which has contacts 589, 590, 591 and 592 wired in series with the counters 582, 551, 581 and 580, respectively. Thus, with each revolution of main drive gear 155, reed switch 586 is closed by magnet 587 passing in close proximity thereto. The closing of reed switch 586 energizes the 24 volt DC. coil of the relay 588 by closing the circuit from line 375 through the magnetic coil of relay 588 and reed switch 586 to the ground connection 376. In parallel with the relay contacts 589, 590, 591 and 592 are momentary contact pushbuttons 593, 594, 595 and 596, respectively. These pushbuttons permit actuation of the counters manually from a remote position when the need arises.

Counters 582, 551, 581 and 580 are constructed with two separate rows of digits. The first row of digits represent the setting of the counter in that it can be preset to a given number while the second row registers and totalizes the occurrence of an external event or function. The two rows of digits are electrically related in that when each indicate the same numerical total an internal circuit is closed whereby an external function can be controlled.

The internal contact of each of the counters is wired in parallel to the 24 volt DC. source, by means of line 597. The electrical components that each counter controls are wired thereto through the respective double pole-double throw switches 598, 599, 600 and 601. These switches enable the disconnecting of the counters from the components they control for the purpose of resetting the counters individually as required. The manual actuation of any of the switches 598, 599, 600 and 601 to the opposite position from that depicted in the circuit diagram results in energizing the magnetic coil of the "lock-out" relay 516 and the indicator light 602, resulting in the deenergization of the weaving apparatus. The indicator lights 603, 604, 605 and 606 are connected in series with the switches 598, 599, 600 and 601, respectively, to provide a visual indication of when the individual counters perform their control function.

The "Filling Inserter Oscillation Counter" 580 controls the oscillation of the tips of the filling yarn inserters across the thickness of the fabric during the weaving process by means of the series connected single pole-double throw magnetic relays 608, 609 and 610 and the magnetic coils 611 and 612. Magnetic coils 611 and 612 are the coils of solenoids 214 and 215 as



shown in FIGS. 10 and 12. With the contacts of relays 608, 609 and 610 in the position as shown in FIG. 76, the 115 volt AC. magnetic coil 611 is energized and upon the closing of the contact within the counter 580 the magnetic relays 608, 609 and 610 are energized resulting in deenergizing the magnetic coil 611 and energizing the magnetic coil 612. Thus, counter 580 and its related relays functionally energize and deenergize the magnetic coils 611 and 612 in accordance with the desired weave pattern.

The "Filling Inserter Retract Counter" 581 functionally controls each filling yarn inserter tip so that the path followed by the tip in the weaving plane follows the contour of that portion of the mandrel which at that moment resides in the weaving plane. While counter 581 is labeled a "retract counter," it is adapted to move the tip both inwardly and outwardly in a radial direction with respect to the vertical axis of the apparatus. Thus, both the "Filling Yarn Oscillation Counter" 580 and the "Filling Inserter Retract Counter" 581 control the movement of the filling yarn inserter tip 181 with the "Filling Yarn Oscillation Counter" 580 adjusting for fabric thickness and the "Filling Inserter Retract Counter" 581 adjusting for the mandrel contour.

The filling yarn inserter tip extender and retract control circuit consists of, in addition to the counter 581, the double pole-double throw switch 600 and the indicator light 605 the two pole-double throw magnetic relays 614 and 615, the reed switch 616, the indicator light 617 wired in parallel with the magnetic coil of relay 614, the magnetic coils 618 and 704 of the respective electromagnetic solenoids 618 and 704 of FIGS. 10 and 12, and the single pole-double throw switch 710. The reed switch 616 is shown in FIG. 10 affixed to the main drive gear support 152 while the switch 710 is mounted on the aforementioned control panel (not shown). The rotation of the main drive gear 155 actuates the reed switch 616 as the magnet 587 carried thereby passes in close proximity thereto.

With the closing of the internal contact of the "Filling Inserter Retract Counter" 581 the magnetic coil of the relay 614 is energized through the normally closed contact 617 of the relay 615. The energization of the relay 614 actuates the contacts 620 and 621 which in turn energizes the 115 volt AC. magnetic coil 618 through the single pole-double throw switch 710 whereby the pin 176 is actuated to engage the star wheel 205 resulting in the retraction of the tip 181 of the filling yarn inserters 180 away from the vertical axis of the mandrel. Similarly when the tip 181 of the filling yarn inserters 180 is to be programmed to extend inwardly toward the vertical axis of the mandrel the single pole-double throw switch 710 is actuated to the opposite position of that shown in the FIG. 76 whereby the magnetic coil 704 of the electromagnetic solenoid 704 is energized to result in actuating the pin 175 into engagement with the star wheel 205. It is obvious that the single pole-double throw switch could be replaced by an additional counter whereby the energizing of either coil 618 or 704 could be controlled automatically in accordance with the mandrel contour.

The relay 614 maintains its energized state until the reed switch 616 is actuated by means of the magnet 587 passing over it. Consequently, regardless of the

number of filling yarn inserters being employed each will be actuated either outwardly or inwardly in accordance with whichever of the magnetic coils 618 or 704 is energized. With the closing of the reed switch 616, the magnetic coil of the relay 615 is energized whereupon its contacts 617 and 623 are actuated. Simultaneously, with the actuation of the contacts 617 and 623 the "Filling Inserter Retract Counter" 581 resets to zero and the relay 614 is deenergized resulting in the deenergization of the relay 615 and either the magnetic coil 618 or 704 depending upon the position of the switch 710 whereupon the sequence of operation is in readiness for a repeat cycle with the counter 581 totalizing the preset count thereof.

The "Ring Drop Counter" 551 functionally controls the dropping of the plurality of concentric ring members 139 having affixed thereto the warp yarns which are to be added to the shed systematically as the diameter of the mandrel increases in order to maintain a constant density fabric. The counter 551 is preset in accordance with the geometrical configuration of the mandrel so that the rate at which warp yarns are added to the shed will provide uniform fabric density. When counter 551 has totalized the number of counts to which it has been preset, the internal contacts thereof close resulting in the energization of the 24 volt DC. magnetic coil of the relay 550. Substantially, simultaneously with the energization of the relay 550, counter 551 is automatically reset to zero by a self-contained automatic reset mechanism, at which time it is ready to repeat the cycle for the dropping of an additional ring. The functioning of the ring drop circuit has been previously discussed.

The "Program Card Deck Counter" 582 controls the indexing of the Jacquard head program index cylinder 31. The control circuit cooperating with the program card deck counter 582 consists of, in addition to counter 582, the double pole-double throw switch 598, and indicator light 603, the single pole-double throw magnetic relay 625 which includes a 24 volt DC. magnetic coil. Relay 625 has its normally open contacts connected in series to the 115 volt AC. line 350 by means of line 626 and to the contacts 363, and other like contacts of the stepping switch 365 by means of line 627.

The "Program Card Deck Counter" 582 is preset in accordance with the total number of cards which comprises program card chain 30 and also in accordance with the rate at which the additional warp yarns are to be added into the fabric during the weaving thereof. When counter 582 has registered a number of counts which equal the number to which it has been preset, its internal contact closes to energize the magnetic coil of relay 625 which results in the closing of contacts 628. The counter 582 is reset to zero by means of the single pole-double throw 24 volt DC. magnetic relay 630 having the coil thereof connected in series with the reed switch 631. Switch 631 is mounted to main drive gear support 152 as depicted in FIG. 10 and is caused to actuate by the passage of the permanent magnet 587 which is mounted on the main drive gear 155. While the reed switch 631 is actuated with every complete revolution of main drive gear 155, resetting of counter 582 does not automatically occur since it can only be caused to reset electrically after the total number of

counts in register equals the number of counts to which it has been preset. Thus, it is apparent that the physical relationship of the reed switches 586 and 631 is important since the dimensional spacing thereof is dependent upon the time required by the Jacquard head to complete the program card indexing function and the rate of rotation of main drive gear 155.

With the energization of the magnetic coil of relay 625, the circuit is prepared for the energization of the appropriate four-way solenoid valve magnetic coil 354 in accordance with the position of the contacts of the stepping switch 365.

#### LOOM DRIVE CONTROL

The operation of the weaving apparatus of this invention, exclusive of the Jacquard head drives, is accomplished by a power train driven by the DC. main drive motor 82 and the DC auxiliary drive motor 96. These motors are controlled by the commercially available, solid state, AC. to DC. motor controllers 633 and 634, respectively. The latter controllers are interconnected to the 115 volt AC. source by means of connections 555 and 556, and the double pole-double throw switch 554.

The power train is also associated with a plurality of electric clutches 635, 86 and 90, and the plurality of electromagnetic brakes 636, 637, 638, 639 and 640. Wired in parallel with each of clutches 635, 86 and 90, are the capacitors 643, 642 and 641, respectively. The capacitors 644, 645, 646, 647 and 648 are respectively wired in parallel with brakes 636 through 640. These capacitors function to dampen the peak voltages generated by energizing and deenergizing the clutches and brakes. The clutches and brakes are powered by means of the AC. to DC. power supply 649 and the 115 volt AC. power connected thereto through connections 555 and 556.

The clutches and brakes are electrically interlocked and are controlled by the circuit consisting of the 24 volt DC. double pole-double throw magnetic relay 650, the 24 volt DC. single pole-double throw magnetic relay 651, the maintained contact switches 652 and 653, the momentary contact pushbuttons 654 and 655 and the indicator lights 656 and 657 which are connected in parallel with the magnetic coils of relays 650 and 651, respectively.

The maintained contact switch 652 functions as the "start-stop" control of the weaving apparatus of this invention in that it controls the energization of the relay 650 which has its contact 658 connected in series with the internal energizing and interlock control circuitry of the clutch and brake power supply 649. The internal interlock circuitry of the power supply 649 precludes the energization of the clutches and brakes simultaneously. Additionally, switch 652 is connected in series to the 24 volt DC. power source through the "lock-out" relays 390 through 429 inclusive and the relays 367, 515 and 516. All of the latter relays must be deenergized before the loom power train can be driven.

Connected in parallel with the "start-stop" switch 652 is the momentary contact pushbuttons 654 and 655 which function as remotely located "jogging" switches. One of these pushbuttons may be located on the ground floor level while the second pushbutton is advantageously located vicinal to the Jacquard heads to enable "jogging" the loom from either location.

The maintained contact switch 653, which is connected in series to the 24 volt DC. power source by line 597 through the normally closed contact 660 of the relay 650, functions as the auxiliary drive motor "start-stop" switch. This switch when closed energizes the magnetic coil of the relay 651 which results in energizing the clutch 90 and deenergizing the clutches 86 and 635. The clutch 635 is integrally mounted with the main drive motor 82. The energization of the auxiliary drive motor and its cooperating clutch 90 enables the driving of the mandrel elevating screw at a relatively high rate of speed for positioning the mandrel in the weave plane.

#### OPERATION

The weaving apparatus of the instant invention utilizes a preformed mandrel as an adjuvant to the fabric weaving process and upon the surface of which the fabric is woven in situ. Consequently, the mandrel must be positioned in the apparatus prior to the beginning of the weaving process.

Mandrel 81 is normally affixed to the mandrel elevating worm 94 and to the star roller guide 122 while the elevating worm is substantially in the fully retracted position. For raising the mandrel 81 at a relatively rapid rate of speed the circuitry is energized by closing the switches 311 and 554. Additionally, switches 598, 599, 600 and 601 must be in the closed position as shown in the circuit diagram lest "lock-out" relay 516 be energized to its open circuit position preventing the starting of the apparatus drive train.

With the 115 volt AC. power on, the DC. drive motors 82 and 96 are operating and with the closing of the auxiliary drive "start" switch 653, the mandrel elevating worm 94 is driven by means of the electric clutch 90. Thus, by utilizing the auxiliary drive motor 96, the mandrel is quickly elevated to the proper position for weaving.

With the mandrel 81 in the correct position to start weaving, the 115 volt AC. power switches 311 and 554 are opened so that the warp yarns can be "drawn-in."

The warp yarns which are to be immediately woven into the fabric structure are affixed to the mandrel while those warp yarns which are to be subsequently added to the fabric during weaving are affixed to the plurality of concentric ring members 139. The warp yarns are "draw-in" with all of the hooks of the Jacquard supported by the knives in the uppermost position; thus, all the warp yarns reside in the upper part of the shed. Subsequent to the "drawing-in" of the warp yarns, the filling yarn, inserters 180 are installed and the respective filling yarns associated with each are tied to the mandrel. Additionally, the program counters 580, 581, 551 and 582 are manually preset to the desired total count at which each is scheduled to perform their respective control functions. The power circuits are reenergized by closing the 115 volt AC. switches 311 and 554, and the 460 volt, three phase, 60 cycle circuit breaker (not shown).

The energization of the Jacquard head hydraulic drive motors 306 through 310 is accomplished by actuating each of the pushbuttons 321 through 325. With the closing of the switches 311 and 554 the DC. motors 82 and 96 are energized. Thus, the apparatus drive train can now be "jogged" by actuating either of the pushbuttons 654 or 655 which results in energizing the



relay 650 and the electromagnetic clutches 86 and 635, or the apparatus drive train can be driven by closing the maintained contact start switch 652 whereupon the relay 650 is energized resulting in energizing the clutches 86 and 635.

With the latter two clutches energized, the filling yarn inserters 180a, 180b, 180c and 180d are driven in a circular path about the vertical axis of the apparatus and coincident therewith, the mandrel is being moved vertically upwardly at a very slow feed rate, i.e., at a rate equal to the weaving rate, by mandrel elevating worm 94.

As the filling yarn inserter 180a moves in a clockwise direction from the position shown in FIG. 10, reed switches 666, 665, 667 and 668 are sequentially actuated which results only in momentarily energizing relays 681 and 669 since the stepping switch 365 is in the position shown on the circuit diagram. With the continued rotation of the filling yarn inserter 180a about the vertical axis of the apparatus, reed switch 372 is actuated which results in energizing the magnetic coil of relay 362 through the contact 670 of the stepping switch 365. With the energization of relay 362, power is applied to the magnetic coil of the time delay relay 360 and to the magnetic coil of the stepping switch 365 by means of the contacts 361 and 383, respectively, of the relay 362 and the contact 389 of the stepping switch 365. The contact 671 thereof functions as the relay hold-in contact as the reed switch 372 is maintained closed only as long as the magnet 700 carried by the yarn filling inserter 180 is in close proximity thereto.

Coincident with the energization of the relay 362, the magnetic coil 355 which is associated with the Jacquard head 16 lift cylinder control valve 69 is deenergized resulting in the grates and knives of Jacquard head 16 being actuated to the center shed position. With the movement of the knives to the center shed position, the limit switch 358 is closed. The closing of the limit switch 358 results in energization of the magnetic coil 353 of the pattern card deck index-card read cylinder control valve 73 and cylinder 53. Thus, a pair of Jacquard program cards are read whereby selected Jacquard hooks are positioned in readiness to be engaged by the knives for manipulation of the warp yarns associated therewith.

The program card chain 30 is not at this time indexed by the program card deck indexing hydraulic cylinder 54 and four-way solenoid valve 76 due to the fact that the program card deck counter 582 internal contact remains open. In fact, none of the counters have yet registered their first count since the magnet 587 has yet to actuate the reed switch 586.

With the continued movement of the filling yarn inserter 180a past the shed area 16' of FIG. 10, which is the shed area controlled by the Jacquard head 16, the filling yarn inserter 180b is approaching entry into the shed area 16'. Prior to the yarn inserter 180b's entry into the shed area 16' the reed switch 371 is actuated thereby resulting in the energization of the relay 366, and the deenergization of the relay 362 and the stepping switch 365. Stepping switch 365 immediately steps to its successive position consisting of the contacts 675, 676, 677, and 678, respectively. If by some malfunction, the stepping switch 365 is not deener-

gized, as for example, the failure of the filling yarn inserter 180b to close the reed switch 371, then it will not step to close the next successive four contacts and the passage of the filling yarn inserter 180b over the next successive reed switch 680 will result in actuating the lock-out relay 367 through the stepping switch contact 681. Simultaneously therewith, the indicator light 378 will be energized through the circuit consisting of the relay contact 370, and the stepping switch contact 379. The actuation of relay 367 results in immediately stopping the apparatus drive train as relay 650 and electric clutches 86 and 635 will simultaneously deenergize. With the deenergization of the clutches, brakes 636 through 640 are energized.

Assuming the apparatus functioned properly with the deenergization of the relay 362, the contact 361 thereof closed to energize the magnetic coil 355 whereupon the grates and knives of Jacquard head 16 are actuated to the full shed position. Simultaneously with the upward motion of the Jacquard head knives, the limit switch 358 is caused to open resulting in deenergizing the magnetic coil 353 and the indexing of one card of the pattern card chain 25.

Subsequent to the completion of the above functions, the time-delay relay 360 closes whereby the magnetic coil 356 of the hydraulic circuit by-pass valve 67 is energized resulting in unloading the hydraulic pump by by-passing the hydraulic fluid directly to the reservoir as a means of preventing heat build-up in the hydraulic system which results from pumping against a high pressure.

The filling yarn inserter 180b now occupies the shed prepared by Jacquard head 16. The continued clockwise movement of the filling yarn inserter 180b actuates the reed switch 680 to execute the same sequence of functions with the Jacquard head 17 and its related shed area 17'. With the filling yarn inserter at the reed switch 680, the filling yarn inserter 180c is at the position corresponding to the reed switch 461; consequently, the shed area 17' is free of any filling yarn inserter which must be the case as the shed thereof is manipulated. The next reed switch actuated by the filling yarn inserter 180b is the switch 683 which results in the Jacquard head operating from the neutral shed position to the full shed position and simultaneously results in the advancing of stepping switch 365 to its next successive position whereby the contacts 684, 685, 686 and 687 are closed.

The filling yarn inserter 180b continues to advance to actuate the reed switch 688 which energizes the control circuitry components for operating Jacquard head 18 to its closed shed position. At this moment, filling yarn inserter 180c is at the reed switch 463 position and the filling yarn inserter 180d is at the position of the reed switch 453. Thus, the shed area 18', controlled by the Jacquard head 18 is void of any filling yarn inserters. The advancement of the yarn filling inserter 180b actuates the reed switch 690 to cause the Jacquard head 18 to manipulate its warp yarns into the full shed position. With the actuation of the reed switch 666 by the filling yarn inserter 180b, Jacquard head 19 operates to the neutral shed position with the filling yarn inserter 180d in the position of the reed switch 455 and the filling yarn inserter 180a is at the position of the reed switch 445.

The actuation of the reed switch 665 by the filling yarn inserter 180b results in the Jacquard head 19 manipulating the warp yarns associated with shed area 19' to the full shed position. The advancement of the yarn filling inserter 180b to the position occupied by the reed switch 668 results in the actuation thereof and the manipulation of the shed of the Jacquard head 20 to its center shed position. At this moment, each of the four filling yarn inserters 180a, 180b, 180c and 180d occupy the four shed areas 19', 16', 17' and 18', respectively, while shed area 20' is void of any filling yarn inserter.

The further advancement of the filling yarn inserter 180b results in the actuation of the reed switch 667 and the operation of the Jacquard head 20, and the warp yarns it controls to the full shed position in preparation for entry of the filling yarn inserter 180b. The successive passage of each of the filling yarn inserters in sequence over each of the reed switches 371, 680, 683, 688, 690, 686, 665, 668, 667 and 372 continues the sequential operation of the Jacquard heads in a manner that is exactly opposite in direction to that of the direction of rotation of the filling yarn inserters.

As the apparatus of this invention continues to weave the three-dimensional fabric upon the outer surface of the mandrel without a malfunction, counters 580, 581, 551, and 582 continue their count of each complete revolution of the main drive gear 155 by the permanent magnet 587 which is affixed thereto actuating the reed switch 586. The filling yarn inserter tips are caused to oscillate in and out radially with respect to the vertical axis of the mandrel in accordance with the program preset into the counter 580 and the control relays and solenoids associated therewith. Filling yarn inserter tips 181 are additionally stepwise retracted or extended with respect to the surface of the mandrel as weaving progresses in accordance to the program preset into the counter 581 by means of the relays 614 and 615, the electromagnetic solenoids 618 and 704, the reed switch 616 and the single pole-double throw switch 710.

The "Ring Drop Counter" 551 executes the dropping of a concentric ring member 139 at the instant it registers a number of counts equal to that to which it has been preset. With the dropping of a concentric ring member, the warp yarns affixed thereto are woven into the fabric in accordance with the punched holes of the cards comprising the program card chain in combination with the cards of the pattern card chain. Program card chain 30 is programmed to be indexed in accordance with the presetting of the counter 582.

If during the weaving operation a filling yarn break occurs in any of filling yarn inserters, one of the reed switches 430 through 469 will be actuated by means of the permanent magnet 242 which is associated with the filling yarn. The actuation of one of these reed switches results in the automatic stoppage of the apparatus within at least 9° of rotation from the point where the break occurred for the lock-out relay wired in series with the respective reed switch will be energized to open the operational control circuit associated with the apparatus drive train, i.e., the plurality of clutches and brakes through deenergization of the relay 650.

With the stopping of the loom, the operator need only observe which of the indicator lights 510 is lighted. This indicates the position of the filling yarn

break whereupon repair may be made and the apparatus may be restarted by actuating the maintained contact pushbutton 512 which resets the relay to the closed circuit position.

We claim:

1. A process for manufacturing a thick-walled seamless and tubular fabric comprising the steps of providing a mandrel having a given axis with a locker warp yarn system comprised of locker warp yarns forming locker warp yarn planes, arranging said locker warp yarn planes coextensively and radially with respect to said axis, traversing said locker warp yarn planes with a continuous and helical filling yarn system comprised of continuous filling yarns forming a plurality of annular and substantially parallel filling yarn planes being concentric and coextensive with said axis and integrally weaving said locker warp yarn and said filling yarn systems together by said locker warp yarns within a given one of said locker warp yarn planes traversing a plurality of said filling yarn planes and locking said filling yarns together by following a predetermined sinuous path.

2. The process of claim 1 wherein said tubular fabric is defined by inner and outer tubular-shaped surfaces said yarns of said locker warp yarn planes following said sinuous path reciprocally between said inner and said outer surfaces.

3. The process of claim 2 wherein said fabric is provided with a third yarn system, said third yarn system being comprised of yarns forming a series of yarn planes being radially aligned with respect to said longitudinal axis.

4. The process of claim 3 wherein said yarn planes of said third yarn system traverse the yarn planes of said filling yarn system and are positioned about said axis to sequentially alternate with the yarn planes of said locker warp yarn system.

5. The process of claim 4 wherein the number of yarns forming the yarn planes of said third yarn system is less than the number of yarns forming the yarn planes of said filling yarn system.

6. The process of claim 5 wherein the yarns of said locker warp yarn system extend around selected yarn decks of said filling yarn system and traverse the remainder of the yarn decks of said filling yarn system.

7. A process for weaving a thick-walled seamless and tubular fabric comprising the steps of

- a. attaching a plurality of warp yarns to a mandrel having a given axis
- b. arranging said warp yarns into warp yarn planes, said warp yarn planes being arranged radially with respect to said axis and extending outwardly from said mandrel;
- c. forming shed sectors by the programmed raising and lowering of selected ones of said warp yarns, said shed sectors remaining stationary with respect to said mandrel and extending radially outward from the surface of said mandrel.
- d. inserting a filling yarn pick into each of said shed sectors formed to build a continuous and helical filling yarn system comprised of annular and parallel yarn decks being concentric and coextensive with said axis said decks each including a plurality of filling yarn picks with said filling yarn picks comprising each deck being separated from each



other by selected ones of said warp yarns, said warp yarns being effective to weave said filling yarn picks into said decks in a predetermined sinuous pattern; and

e. moving said mandrel along a vertical path at a rate equal to the rate of deck formation to position said shed sectors to receive and weave additional filling yarn picks for the formation of additional yarn decks.

8. The process of claim 7 wherein said filling yarn is inserted into said shed sectors by following a helical path about said mandrel.

9. The process of claim 8 wherein selected ones of said shed sectors remain stationary during the insertion of a filling yarn pick therein while the remainder of said shed sectors are being adapted to receive a filling yarn pick.

10. The process of claim 9 wherein said yarn shed sectors are manipulated by at least two Jacquard heads with each of said Jacquard heads controlling a given shed sector.

11. The process of claim 10 wherein said filling yarn picks are inserted into said shed sectors by at least one filling yarn inserter, the number of filling yarn inserters being at least one less than the number of Jacquard heads controlling said shed sectors.

12. The process of claim 11 wherein said Jacquard heads are programmed to manipulate their respective shed sectors when said shed sectors are free of said filling yarn inserters.

13. The process of claim 12 wherein said warp yarns are comprised of locker yarns and stuffer yarns, said Jacquard heads positioning said stuffer yarns in said fabric to separate said filling yarns forming a filling yarn deck and controlling said locker yarns to loop around and extend between said filling yarns decks, said locker yarns being effective to maintain the integrity of said filling yarn decks and to weave said filling yarns into said fabric.

14. The process of claim 13 wherein the radial distance from said filling yarn decks to said axis varies in accordance with the exterior shape of said mandrel.

15. The process of claim 14 wherein said locker yarns and stuffer yarns are added to said shed sectors and incorporated into said fabric as the radial distance between said axis and said filling yarn decks increases and are removed from said shed sectors as the radial distance between said axis and said filling yarn decks decreases by said Jacquard heads in accordance with a predetermined pattern, said pattern being dependent upon the exterior shape of said mandrel whereby the density of said fabric is maintained at a predetermined constant.

16. The process of claim 15 wherein said locker yarns and said stuffer yarns are arranged in an alternating sequence about said mandrel.

17. The process of claim 16 wherein said woven fabric is removed from said mandrel.

18. The process of claim 16 wherein said mandrel is adapted to move upwardly along said vertical axis and wherein said mandrel is cone-shaped with said exterior surface tapering outwardly from top to bottom.

19. The process of claim 18 wherein said stuffer yarns and said locker yarns which are to be added to said fabric to maintain a constant yarn density as the

radial distance between said axis and said filling yarn decks increases are held out of said shed sectors by said Jacquard heads until programmed to be woven into said fabric.

20. The process of claim 12 wherein said warp yarns are comprised of locker warp yarns and stuffer warp yarns, said Jacquard heads forming said shed sectors to position said locker warp yarns in said fabric to extend between adjacent filling yarns decks and to loop around selected filling yarn decks and to align said stuffer warp yarns within said fabric to be positioned between adjacent filling yarns, said locker warp yarns being effective to maintain the integrity of said filling yarn decks and to lock said filling yarns in said fabric, said stuffer warp yarns increasing fabric tensile strength along its length.

21. The process of claim 20 wherein said locker warp yarns continuously reciprocate between the inner and the outer surfaces of said fabric along a substantially sinuous path.

22. The process of claim 21 wherein said filling yarn decks are concentrically arranged about said axis of said mandrel with the radial distance from said filling yarn decks to said axis varying in accordance with the exterior shape of said mandrel.

23. The process of claim 22 wherein said stuffer warp yarns and said locker warp yarns are added to said shed sectors and incorporated into said fabric as the radial distance between said axis and said filling yarn decks increases and are removed from said shed sectors as the radial distance between said axis and said filling yarn decks decreases by said Jacquard heads in accordance with a predetermined pattern, said pattern being dependent upon the exterior shape of said mandrel whereby the density of said fabric is maintained at a predetermined constant.

24. The process of claim 23 wherein said locker warp yarns and said stuffer warp yarns are arranged in an alternating sequence about said mandrel.

25. The process of claim 24 wherein said woven fabric is removed from said mandrel.

26. The process of claim 24 wherein said mandrel is adapted to move upwardly along said axis and wherein said mandrel is cone-shaped with said exterior surface tapering outwardly from top to bottom.

27. A process for weaving a thick-walled fabric about selected exterior surfaces of a shaped vertically arranged mandrel, said fabric being defined by outer and inner surfaces with said inner surface assuming the shape of said mandrel exterior surface with which it is contiguous, said process comprising the steps of:

- a. associating a plurality of warp yarns with the upper portion of said mandrel, said warp yarns lying in a substantially horizontal plane being perpendicular to the vertical axis of and circumambient to said mandrel, said warp yarns extending outwardly from said mandrel surface and extending to a warp yarn source and being radially arranged with respect to said vertical axis;
- b. dividing said horizontal plane of warp yarns into at least two shed sectors;
- c. providing each of said warp yarn shed sectors with a Jacquard head, said Jacquard head being connected to each of said warp yarns in said shed sector and being adapted to raise selected warp yarns

and to lower the remainder of said warp yarns in accordance with a predetermined program to form a sequence of shed sectors;

- d. inserting a filling yarn pick into each of said shed sectors formed by means of filling yarn inserters being less in number than said Jacquard heads, said filling yarn inserters traveling through connecting shed sectors formed by said Jacquards along a continuous path about said vertical axis, said shed sectors being changed and adapted to receive said filling yarn inserter only in the absence of a filling yarn inserter therein;
- e. weaving said filling yarns in said warp yarns to form a continuous and helical filling yarn system being coextensive with said mandrel and concentric with respect to said mandrel vertical axis, said filling yarn system comprising substantially parallel and annular filling yarn decks being perpendicular to said axis with each deck being comprised of a plurality of concentrically arranged filling yarn picks;
- f. moving said mandrel along said vertical axis at a rate equal to the rate of deck formation whereby said warp yarn shed sectors are maintained in a fixed plane with respect to the filling yarn inserter tip to receive and weave additional filling yarn picks for the formation of additional decks; and
- g. removing said thick-walled fabric from said mandrel upon the completion of said decks.

28. The process of claim 27 wherein said filling yarn picks comprising a filling yarn deck are separated from each other and are locked into said fabric by said warp yarns.

29. The process of claim 28 wherein a single filling yarn inserter is employed, said filling yarn decks being comprised of a continuous filling yarn supplied by said single filling yarn inserter.

30. The process of claim 28 wherein said filling yarn picks are supplied to at least three said shed sectors by two filling yarn inserters and with each of said shed sectors being provided with a Jacquard head, said filling yarn deck being comprised of a number of filling yarns, said number being divisible by two, said filling yarn decks being comprised of a first set of adjacent and concentrically arranged filling yarn picks being supplied by a first filling yarn inserter and a second set of adjacent filling yarn picks, said second set of adjacent filling yarn picks being supplied by a second filling yarn inserter and being concentrically arranged with respect to each other and said first set of filling yarn picks.

31. The process of claim 71 wherein the shed is divided into at least five sectors with each of said sectors being individually controlled by a respective Jacquard head and wherein said filling yarns are supplied to said shed sectors by four filling yarn inserters to form said filling yarn decks with the number of filling yarn picks comprising each of said decks being divisible by four, said filling yarn decks having four sets of filling yarns with the filling yarn of each set being continuous and being concentrically arranged with each other and the filling yarns of other sets with each set of filling yarns being supplied by a single filling yarn inserter.

32. The process of claim 31 wherein each of said filling yarn inserters supplies filling yarn to only one predetermined set.

33. The process of claim 32 wherein the number of filling yarn picks comprising each set may be increased and decreased during weaving by said Jacquard heads selectively controlling the formation of said shed sectors and by the simultaneous respective addition and elimination of warp yarns to accommodate the separation of adjacent filling yarn picks from each other and the locking of said filling yarn picks within said fabric.

34. The process of claim 28 wherein only a selected number of warp yarns initially associated with the upper portion of said mandrel are employed by said Jacquard heads to form said shed sectors said Jacquard heads incorporating the remainder of said warp yarns into said fabric in accordance with said predetermined program.

35. The process of claim 34 wherein said mandrel is substantially cone-shaped with said exterior surface tapering outwardly from top to bottom.

36. The process of claim 35 wherein the number of said warp yarns employed by said Jacquard heads to form said shed sectors increases proportionally to the increase in radial distance between said filling yarn decks and said vertical axis.

37. The process of claim 36 wherein additional warp yarns are added to said shed sectors by concentric ring members, said concentric ring members normally being positioned above said mandrel and being adaptable to be dropped down into close proximity to said mandrel in accordance with said predetermined program, said additional warp yarns extending from a source to said concentric rings and being connected to selected Jacquard heads, said Jacquard heads incorporating said warp yarns into said shed sectors selectively upon the dropping of said concentric ring members.

38. An apparatus for weaving a thick-walled three-dimensionally shaped fabric comprising:

- a. a shaped mandrel adaptable for movement along a vertical axis;
- b. a warp yarn source circumambient to said mandrel for supplying warp yarns thereto, said warp yarn source maintaining said warp yarns under tension;
- c. means for attaching said warp yarns to said mandrel, said warp yarns being positioned to extend horizontally and radially outwardly from said mandrel;
- d. Jacquard means being in communication with selected warp yarns for forming warp yarn shed sectors in accordance with a predetermined program;
- e. filling yarn inserter means movable about said mandrel along a defined path and through said shed sectors for depositing a filling yarn pick in each of said shed sectors, said filling yarn inserter means and said Jacquard means cooperating to weave a continuous and helical filling yarn system being concentric with respect to said mandrel vertical axis and being comprised of a plurality of substantially parallel and annular filling yarn decks being perpendicular to said axis with each deck being comprised of a plurality of concentrically arranged filling yarn picks, said Jacquard means controlling selected warp yarns to traverse along a sinuous path said filling yarn decks and to interlock contiguous filling yarn decks to each other to form a three-dimensional fabric having a portion



being shaped in accordance with the exterior surface of said mandrel.

39. The apparatus of claim 38 wherein said apparatus includes a vertically extending frame having a vertical axis being common with said mandrel longitudinal axis.

40. The apparatus of claim 39 for weaving said shaped fabric wherein said Jacquard means is a plurality of Jacquard heads and said filling yarn inserter means is a filling yarn inserter with the number of Jacquard heads exceeding the number of filling yarn inserters at least by one, said Jacquard heads and said filling yarn inserter being mounted on said frame.

41. The apparatus of claim 40 for weaving said shaped fabric wherein each of said Jacquard heads controls a specific sector of said warp yarns, said Jacquard heads being adaptable to change said shed sector when said sector is free of said filling yarn inserter.

42. The apparatus of claim 41 for weaving said shaped fabric wherein said filling yarn inserter is mounted for movement through said shed sectors and about said mandrel along said defined path on a discontinuous rail, said discontinuous rail being mounted on said frame and being comprised of spaced apart rail segments, said rail segments being positioned substantially in said shed sectors and arranged circumambient to said mandrel and being positioned to allow for the changing of said shed sectors by said Jacquard heads whereby said warp yarns pass between said rail segments.

43. The apparatus of claim 42 for weaving said shaped fabric wherein said discontinuous rail is circular in shape and concentrically arranged about said frame vertical axis.

44. The apparatus of claim 43 for weaving said shaped fabric wherein said filling yarn inserter is moved along said discontinuous rail about said mandrel by drive means, said drive means being comprised of an annular main drive gear mounted on said frame and concentrically about said frame vertical axis, said main drive gear being adapted for rotation about said frame vertical axis, motor means inducing the rotative movement in said main drive gear, a first vertically arranged pinion gear disposed adjacent each of said rail segments for meshing engagement with a toothed rack segment associated with said filling yarn inserter, a second vertically arranged pinion gear in meshing engagement with the main drive gear with said first and second pinion gears being connected to a common shaft rotatively mounted in said frame whereby the rotative motion of said main drive gear moves said filling yarn inserter around said discontinuous rail.

45. The apparatus of claim 44 for weaving said shaped fabric wherein said filling yarn inserter is adapted to engage selectively at least two of said first pinion gears simultaneously when passing from one of said rail segments to an adjacent rail segment.

46. The apparatus of claim 45 for weaving said shaped fabric wherein said filling yarn inserter is provided with a retractable tip, said tip adapted to insert said filling yarn pick in the vertex of said shed sector substantially adjacent to said mandrel and being movable radially with respect to said frame vertical axis.

47. The apparatus of claim 46 for weaving said shaped fabric wherein said tip is caused to oscillate and

extend or retract in accordance with a predetermined program by counting means to accommodate for the fabric thickness and the change in the exterior shaped of said mandrel.

48. The apparatus of claim 47 for weaving said shaped fabric wherein said counting means includes index means mounted on said filling yarn inserter, tip actuation mechanism mounted on said filling yarn inserter and connecting said index mechanism with said tip to selectively move said tip incrementally upon the actuation of said index means, index actuation means mounted on said frame for selectively engaging and actuating said index means, a first and second counter means connected to and selectively energizing said index actuation means and a power source for said counter means, said tip being caused to oscillate upon the energization of said index actuation means by said first counter means and said tip being caused to extend or retract upon the energization of said index actuation means by said second counter means.

49. The apparatus of claim 48 for weaving said shaped fabric wherein said main drive gear has mounted thereon a fabric compactor, said fabric compactor being comprised of a base plate being secured to said main drive gear, a plate member being slidably mounted in said base plate and positioned to extend radially inward toward said frame vertical axis, impactor means rotatively mounted on the inward extending end of said plate member, said impactor means being adapted to force said filling yarn having been inserted into the last formed shed sectors into said fabric and having a surface normally residing adjacent and in slidable contact with said mandrel exterior surface and spring means connected to said base plate and said plate member for maintaining said contact between said impactor means and said mandrel.

50. The apparatus of claim 49 for weaving said shaped fabric wherein said impactor means is comprised of a hub having an axis of rotation and a plurality of blades extending outwardly from said hub and being radially aligned with said axis of rotation, said blades being adapted to force said filling yarns into said fabric.

51. The apparatus of claim 48 for weaving said shaped fabric wherein said mandrel is moved along said vertical axis and said main drive gear is rotatively moved simultaneously by said motor means, said motor means moving said mandrel along said vertical axis at a rate equal to the rate of filling deck formation.

52. The apparatus of claim 51 for weaving said shaped fabric wherein said motor means includes a motor, a power source for said motor, a first gear reducer and a second gear reducer each being connected to said motor, a second pinion gear mounted for rotation in said frame and being connected to said first gear reducer and being in meshing engagement with said main drive gear and elevator means connected to said second gear reducer and supporting said mandrel for raising and lowering said mandrel.

53. The apparatus of claim 52 for weaving said shaped fabric wherein said elevator means is comprised of a vertically arranged threaded shaft being reversibly rotatable and an auxiliary motor connected thereto and to a power source, said threaded shaft including means for receiving and supporting said mandrel.

54. The apparatus of claim 53 for weaving said shaped fabric wherein said motor and said auxiliary motor are interconnected to said threaded shaft by means of a first and a second electric clutch, and said motor is connected to said second pinion gear by means of a third electric clutch, said first, second, and third electric clutches being electrically controlled to permit only one of said motors to power said threaded shaft at a time.

55. The apparatus of claim 54 for weaving said shaped fabric wherein said motor is interconnected to said threaded shaft by means of said second electric clutch and to said second pinion gear by means of said third electric clutch, said second and said third electric clutches being electrically controlled to actuate said main drive gear and said elevator means synchronously.

56. The apparatus of claim 55 for weaving said shaped fabric wherein a filling yarn break detector is provided, said filling yarn break detector being comprised of magnet means mounted on said filling yarn inserter, magnetically actuatable reed switches mounted on said frame and said second and said third electric clutches normally being electrically energized and electrically connected to said magnetically actuatable reed switches, said magnet adapted to be moved into communication with and to actuate a reed switch upon the breaking of a filling yarn whereupon said actuated reed switch deenergizes said second and said third electric clutches which results in the disengagement of said motor from said second pinion gear and said elevator means.

57. The apparatus of claim 52 for weaving said shaped fabric wherein said mandrel is provided with a mandrel guide, said mandrel guide being adapted to maintain the movement of said mandrel along said frame vertical axis and comprising a vertical track including at least three vertically extending and parallel rods being parallel to said frame vertical axis and being mounted on said frame and a spider guide having a center hub which receives the upper extending portion of said mandrel and a plurality of arms connected to and extending radially outwardly from said hub, said arms being equal in number to said rods and having ends being slidably received by said rods to adapt said spider guide to slide vertically along said track.

58. The apparatus of claim 51 for weaving said shaped fabric wherein said warp yarns are secured to the upper portion of said mandrel and said motor means is adapted to move said mandrel upwardly along said vertical axis at a rate equal to the rate of filling yarn deck formation.

59. The apparatus of claim 58 for weaving said shaped fabric wherein said mandrel is substantially cone-shaped with said exterior surface tapering outwardly away from said vertical axis to provide for an increase in cone diameter from top to bottom.

60. The apparatus of claim 59 for weaving said shaped fabric wherein said Jacquard heads are provided with means adapted to supply said shed sectors with added warp yarns as said mandrel is raised by said motor means, said added warp yarns being incorporated into said fabric to maintain a substantially uniform fabric density throughout the vertical length of said fabric.

61. The apparatus of claim 60 for weaving said shaped fabric wherein said Jacquard heads include a plurality of hooks mounted for vertical movement, heddles connecting said hooks with individual warp yarns, knives for engaging and raising selected hooks, means for raising said knives, bars for receiving those hooks being free of said knives and for lowering said received hooks, means for lowering said bars, means for selectively positioning said hooks on respective bars and knives, levitator means for positioning selected hooks out of engagement with both knives and bars for maintaining the connected yarns out of said shed sectors and independent of the Jacquard shedding motion and levitator release means associated with said levitator means for selectively releasing said hooks from said levitator means to allow said connected warp yarns to form a part of said shed sectors and said Jacquard shedding motion and to be incorporated into said fabric to maintain a substantially uniform fabric density as the diameter of said cone increases.

62. The apparatus of claim 59 for weaving said shaped fabric wherein warp yarn addition ring means are provided, said warp yarn addition ring means receiving a plurality of warp yarns from said warp yarn source and maintaining said warp yarns above said shed sectors until programmed to be incorporated into said shed sectors to maintain a substantially uniform fabric density as the diameter of said cone increases.

63. The apparatus of claim 62 for weaving said shaped fabric wherein said warp yarn addition ring means is comprised of a plurality of ring members being concentrically arranged about said frame vertical axis and adapted to receive said warp yarns, support arms connected to and extending radially outwardly from each of said ring members, retractable arm supports receiving said support arms and means for actuating said retractable arm supports to allow said ring members to drop and to place said warp yarns in said shed sectors.

64. The apparatus of claim 63 for weaving said shaped fabric wherein said means for energizing said retractable arm supports is comprised of solenoids mounted on said frame and connected to each of said retractable arm supports, electrical circuit means adapted to commonly connect said solenoids which function as a set to receive the arms of a common ring member and a ring drop counter connected to said solenoids by said electrical circuit means, said ring drop counter being adapted to energize sequentially the solenoids connected to the sets of retractable arm supports to allow each of said ring members to drop individually whereby said warp yarns attached thereto may be incorporated into said shed sectors.

65. The apparatus of claim 64 for weaving said shaped fabric wherein said ring drop counter is adapted to count the revolutions of said main drive gear and to cause said solenoids actuating a single set of retractable ring support arms to be energized after a predetermined number of revolutions of said main drive gear has been recorded.

66. The apparatus of claim 65 for weaving said shaped fabric wherein said ring drop counter includes a reed switch mounted on said frame and wherein a magnet is mounted on said main drive gear to pass in close proximity to said reed switch and being adapted to ac-

tuate said reed switch whereupon said actuation is recorded by said ring drop counter.

67. The apparatus of claim 38 for weaving said shaped fabric wherein said warp yarn source maintaining said warp yarns under tension is comprised of a plurality of support rods, said rods having a flat surface running lengthwise with respect thereto and a plurality of spools rotatably mounted on said rods, each of said spools having an outer surface for receiving a length of warp yarn and being adapted to define a passageway having a diameter larger than the diameter of said rods and a spring torsionally wound in said passageway, said coiled spring having a flat end adapted to engage said rod flat surface, a body portion wound about said flat surface and a friction end adapted to frictionally engage said passageway wall, said flat end preventing said spring from rotating about said rod and said spring body portion forcing said friction end against said passageway wall to adapt said spool to be rotated relative to said spring only after the frictional force between said spring friction end and said passageway wall has been overcome.

68. Apparatus for weaving a thick-walled three-dimensionally shaped fabric comprising:

- a. a shaped mandrel mounted for movement along a

vertical axis;

- b. a warp yarn source circumambient to said mandrel for supplying warp yarns thereto;
- c. means maintaining said warp yarns under tension;
- d. means for attaching said warp yarns to said mandrel, said warp yarns extending horizontally and radially outwardly from said mandrel;
- e. a plurality of Jacquard heads controlling selected warp yarns for forming shed sectors in accordance with a predetermined program;
- f. filling yarn inserter means movable about said mandrel along a defined path and through said shed sectors for depositing a continuous filling yarn through each of said shed sectors, said filling yarn inserter means and said Jacquard means cooperating to weave a three-dimensional fabric having a portion shaped in accordance with the exterior surface of said mandrel.

69. The process of claim 1 wherein said fabric is provided with a third yarn system, said third yarn system being comprised of yarns forming a series of yarn planes being radially aligned with respect to said longitudinal axis.

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