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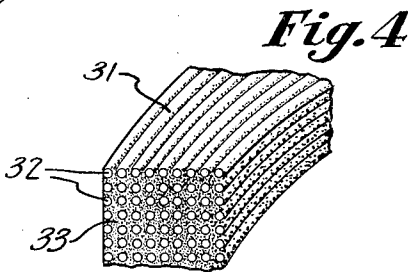
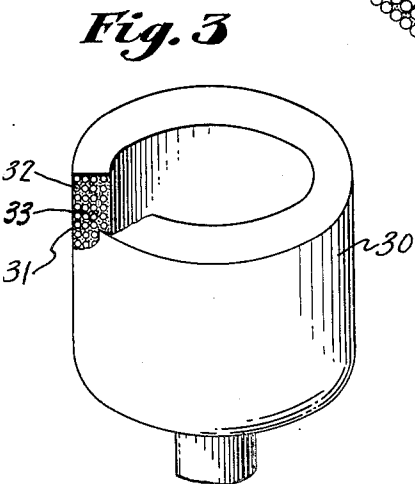
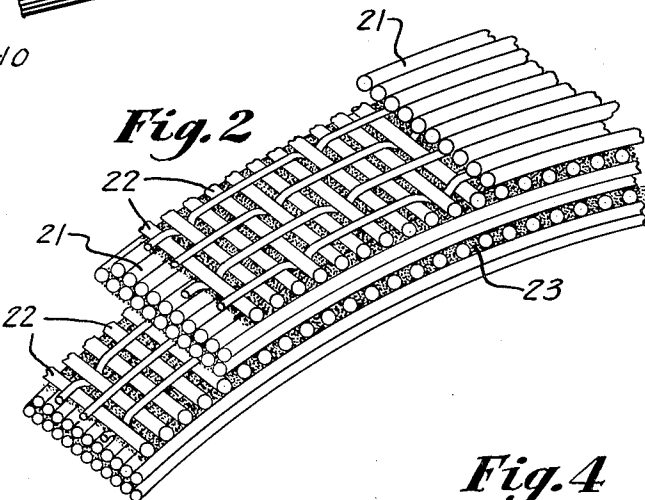
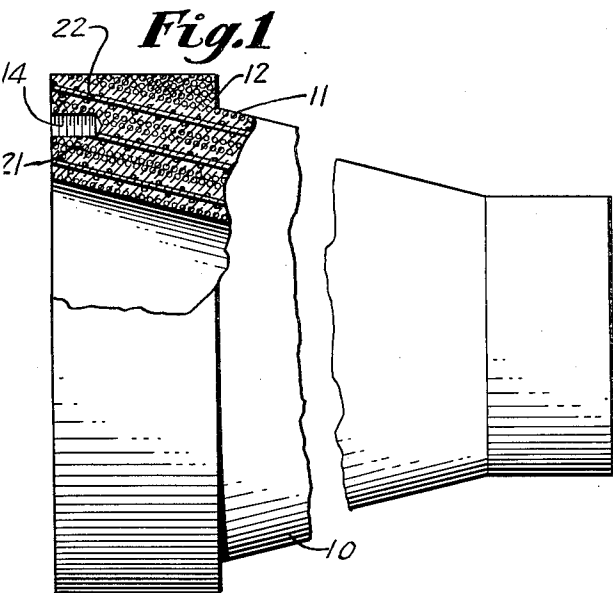
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2,594,693

HOLLOW CIRCULAR ARTICLE AND METHOD OF MAKING SAME

Filed Dec. 7, 1948

2 SHEETS—SHEET 1



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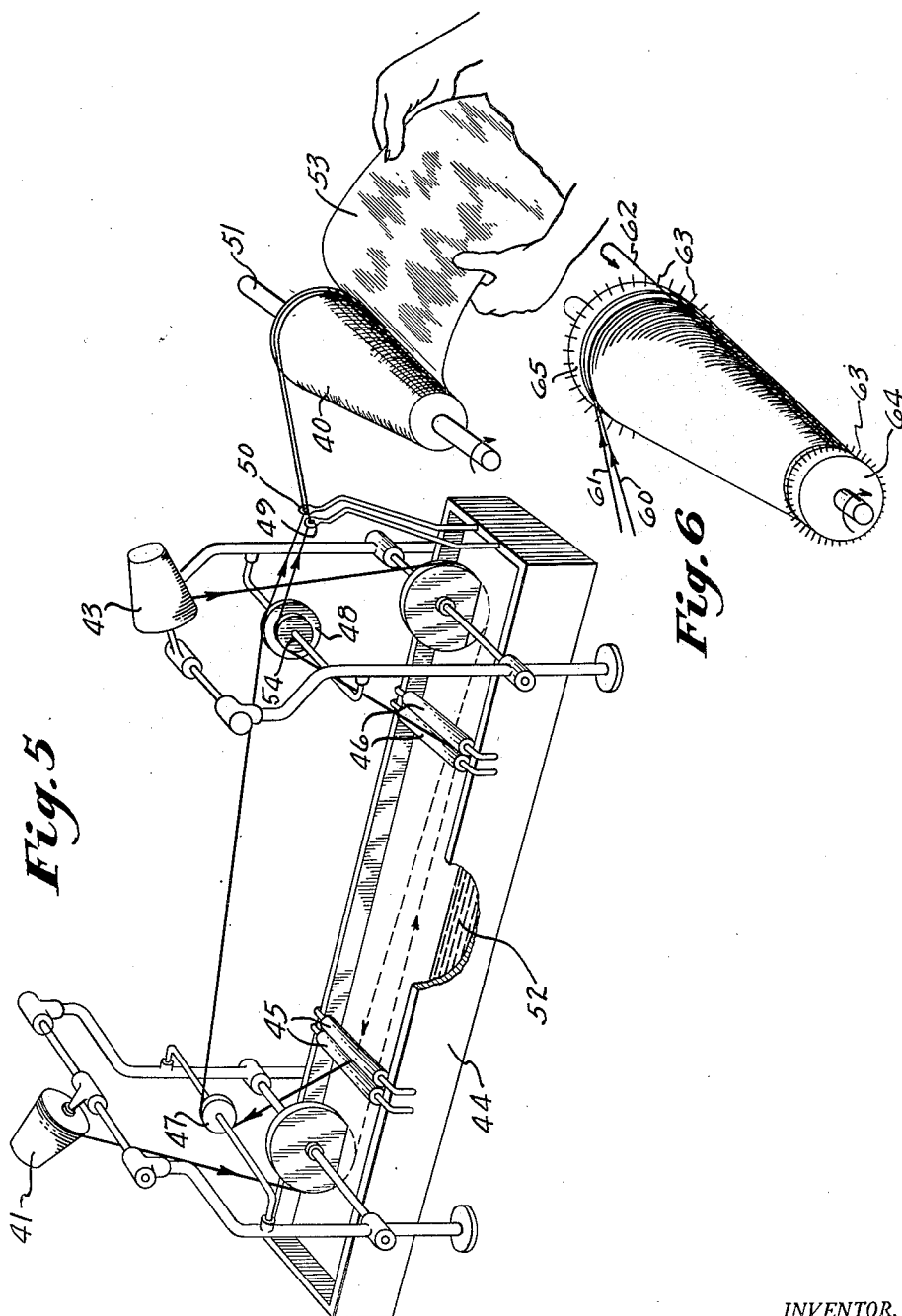
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2 SHEETS—SHEET 2



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HOLLOW CIRCULAR ARTICLE AND
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Application December 7, 1948, Serial No. 63,882

18 Claims. (Cl. 57-76)

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The present invention relates to novel hollow circular objects adapted to be subjected to high peripheral stress such as centrifugal bowls of the type used in centrifugal separating and/or clarifying machines and as spinning buckets in the manufacture of rayon and the like; conduits adapted to carry fluids under high pressure; and the like. The invention also relates to a novel process for preparing such objects. More particularly, the present invention relates to such objects prepared from laminated glass yarn arranged and applied in a novel manner, and to a novel process for fabricating the objects from glass yarn. While it will be understood that the present invention is adapted to the manufacture of high pressure conduit means, the invention will be described with particular emphasis on centrifugal bowls as set forth above. This application is a continuation-in-part of application Serial Number 770,925, filed August 27, 1947 (now abandoned).

Centrifugal bowls of the type used in centrifugal separating and/or clarifying machines and as spinning buckets are, of course, subjected to very high forces in use. Depending upon the particular use and attendant conditions, the direction of the principal stress varies. For instance, in centrifuges, the preponderant stress is generally in a direction at right angles or transverse, to the axis of rotation, that is in a peripheral direction, although in certain installations a substantial proportion of the stress may be directed in the axial direction. In spinning buckets, however, substantially all of the stress is exerted in the peripheral direction with relatively little in the axial direction. Centrifugal bowls of the type described have, in the past, been made for the most part from metal and metal alloys. Various disadvantages in the use of metals such as low specific yield point as compared to the metal's ultimate specific tensile strength, relatively great weight, and relatively high coefficient of thermal expansion, have led investigators in search of light weight substitutes having high tensile strength.

For instance, it was suggested to form a spinning bucket from laminated resin-impregnated glass fabric. In a later development, it was suggested to substitute, for the all-glass fabric, a combination glass and cotton fabric woven in such a manner that the glass yarn provided the warp and the cotton yarn the fill. In this development, laminations were formed of the fabric so that the glass yarn extended peripherally around the walls of the bucket, while the cotton

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yarn extending in the axial direction served as a cushion for the glass yarn, preventing crushing during the molding operation. While these products were satisfactory, they offered no significant advantages over the use of similarly shaped products made from steel. Moreover, with both the glass fabric and the glass-cotton fabric, difficulty was encountered in forming more complex shapes such as conical, and part conical-part cylindrical centrifugal bowls. In addition, due to the porous nature of both the glass fabric and the glass-cotton fabric, there was danger of voids being introduced within and between the laminae which would impair the strength of the article. Furthermore, due to the woven nature of the fabric, a certain amount of "give" was encountered when heavy forces, such as centrifugal force, were applied to the laminated article causing ultimate deterioration of the article.

It is, therefore, a principal object of the present invention to provide a hollow circular object of the type which is subjected to heavy distorting forces, especially in the peripheral direction, such as centrifugal bowls and the like, with which the difficulties hereinabove mentioned are not encountered.

A further object of the invention is to provide a novel centrifugal bowl composed chiefly of glass yarn which possesses a marked improvement in tensile strength compared to previous laminated glass fabric articles.

Another object is to provide a novel light weight centrifugal bowl possessing high tensile strength in the directions required and which does not become distorted upon the application of high tensional forces.

Still another object is to provide a novel process for the manufacture of the above-described product.

Other objects will become apparent from a consideration of the following specification and the claims.

The novel hollow, circular product of the present invention capable of resisting high forces in tension comprises layers of helically wound taut glass yarn impregnated with and held in place by a cured thermosetting resin binder. The helically wound glass yarn provides the desired tension strength in the peripheral direction, that is circumferentially in a direction substantially at right angles or transverse, to the longitudinal or axial direction, and as will appear hereinafter the tensile strength provided with such an arrangement is markedly greater than that

provided by glass yarn in the form of a woven fabric. Additional strength, if desired, in the longitudinal or axial direction is also provided in accordance with the present invention, by substantially straight resin-impregnated glass yarn lying substantially in a longitudinal or axial direction and substantially at right angles to, or transverse to, the direction of the aforementioned helical glass yarn windings. In the case glass yarn is also provided in the longitudinal or axial direction the product will comprise alternate superimposed layers of helically wound taut glass yarn in the peripheral direction and substantially straight glass yarn lying in the longitudinal or axial direction all impregnated with and held in place by the cured thermosetting resin binder. As will appear herein the substantially straight glass yarn in the axial or longitudinal direction is conveniently provided by uni-directional glass fabric more fully described hereinafter.

The essential features of the product and process of the present invention will be better understood by a consideration of the drawings in which:

Figure 1 is an elevational view partly in section of one form of the product of the present invention.

Figure 2 is a relatively large-scale, detailed fragmentary perspective view of the wall of the bowl shown in Figure 1 showing the arrangement of alternate layers of taut helically-wound resin-impregnated glass yarn in the peripheral direction and substantially straight resin-impregnated glass yarn in the axial direction, the latter being provided by uni-directional glass fabric the maximum yarn lay of which lies in the axial or longitudinal direction.

Figure 3 is an elevational perspective view partly in section of another form of the product of the present invention.

Figure 4 is a fragmentary perspective view in relatively large scale illustrating the arrangement of helically-wound resin-impregnated yarn forming the wall of the bowl shown in Figure 3.

Figure 5 is an illustration of means which may be used to helically wind the resin-impregnated glass yarn in the formation of one form of the product of the present invention, and, if desired, for applying alternate superimposed layers of taut helically-wound resin-impregnated glass yarn and substantially straight resin-impregnated glass yarn in the form of uni-directional glass fabric, in the axial direction.

Figure 6 is an illustration of means which may be used in conjunction with the apparatus shown in Figure 5 for applying alternate superimposed layers of taut helically-wound resin-impregnated glass yarn and substantially straight resin-impregnated unwoven glass yarn in the axial or longitudinal direction.

As will be noted from the above, the strength-giving reinforcements within the structure of the product of the present invention are, in the peripheral direction, taut helical windings of unwoven resin-impregnated glass yarn, and in the longitudinal or axial direction, if necessary, substantially straight resin-impregnated glass yarn. The advantages of such a structure are many. In the first place, the employment of unwoven yarn wound in the direction where the greatest stresses are normally encountered, namely in the peripheral direction, utilizes to the maximum extent the normally high tensile strength of glass yarn. Since the yarn is not woven, there is no danger of crushing the respective fibres at the

points of juncture between crossing yarns. For the same reason there are no kinks as is the case with the respective yarns in a woven fabric which would allow the structure to "give" or yield upon the application of stresses. Then too, since the unwoven yarns are wound in substantially the same direction, i. e. in the peripheral direction, the interstices which are encountered in woven fabric are eliminated and a greater amount of the strength-giving reinforcement, i. e. glass yarn, can be compacted into a given space. In addition, however, since the glass yarns are maintained under tension as they are being helically wound in building up the product a more compact structure is provided and the helically wound yarns in the final product are taut providing walls having a yield point approaching the ultimate tensile strength of the yarn. As a result of the foregoing, articles, such as centrifuge bowls may be prepared having a tensile strength in the peripheral direction as high as 100,000 p. s. i. or higher, and generally the articles will exhibit a yield point strength approximately twice that of metal bowls of comparable size and shape, while at the same time being substantially lighter in weight and having a very low coefficient of thermal expansion.

From the standpoint of the process the use of resin-impregnated unwoven glass yarn as the reinforcement in the peripheral direction permits the use of pre-tension in the building up of complex shapes. In other words, the building up of complex shapes by winding glass yarn while at the same time applying tension to the yarn is relatively simple as compared to the lamination of woven fabrics.

What has been said above also applies to the use of substantially straight resin-impregnated glass yarn, if employed, as the reinforcement in the longitudinal or axial direction.

As stated, according to the broader aspects of the present invention there are provided hollow circular articles adapted to be subjected to high tensional forces in the peripheral direction which comprise a built-up structure of taut helically wound resin-impregnated glass yarn. As also stated, in many cases, relatively high tensile strength in the axial or longitudinal direction is required, and, in accordance with the preferred embodiment of the present invention, is provided by layers of substantially straight resin-impregnated glass yarn lying in the axial or longitudinal direction. Referring to the glass yarn that may be employed, it may be any of those glass yarns well known in the fibre glass industry. The term "yarn" is used herein to refer to glass fibre elements composed of a plurality of individual fibres or filaments. The yarn may be prepared from staple glass fibres, that is fibres having a length varying from about 8 to about 15 inches, or from continuous filaments having an indeterminate length limited only by the amount of filament that can be wound on a bobbin. The yarn may be of the twisted type or of the relatively untwisted type. In the latter case, just sufficient twists are made to hold the many fibres or filaments together into a yarn, and since this presents the least possibility of kinking, the relatively untwisted type of yarn is preferred.

Both the staple glass fibres and the continuous filaments are available in a number of diameters affording different tensile strengths. For instance, staple fibres and continuous filaments are available in sizes ranging from a group having an average diameter of about 0.00021 inch up to a

group having an average diameter of about 0.005 inch. Generally, the smaller the diameter of the fibre or filament, the higher the ultimate tensile strength of the fibre or filament. For this reason, it is preferred that the yarn employed be prepared from fibres or filaments having a diameter in the lower half of the above-recited range. Glass yarn prepared from staple glass fibres possesses a lower tensile strength and thus a correspondingly lower yield point strength than does yarn prepared from continuous glass filaments, and for this reason yarn prepared from continuous glass filaments is preferred. A typical example of glass yarn that may be employed in the present invention is one prepared by first gathering into a bundle 204 continuous glass filaments of such a size that 22,500 yards of a filament weighs one pound. Two of such bundles are then lightly twisted together to form a strand, five of which strands are lightly twisted together to form the yarn.

With respect to the glass yarn which may be employed, if desired, as the reinforcement in the axial or longitudinal direction, it may be any of the glass yarns as outlined above. Generally, however, from the standpoint of ease of fabrication of the product of the invention, the yarn supplying reinforcement in the axial or longitudinal direction will be in the form of a uni-directional glass fabric woven from the glass yarn described above. Such uni-directional glass fabric, as is well known in the art, is fabric, woven from glass yarn, in which the amount by weight of glass yarn in the maximum lay direction is at least about 75% and preferably about 90% of the total glass yarn lay in the fabric. Such fabrics are prepared by weaving either larger yarns or a greater number of yarns in one direction or by weaving a greater number of larger yarns in one direction, and the direction in the fabric in which the greater proportion by weight of glass yarn lies is referred to as the direction of maximum yarn lay. Obviously, such fabrics may be prepared with the maximum yarn lay comprising either the warp or the fill of the fabric, depending upon the choice of fabric weave. In any event, in the product of the invention when uni-directional glass fabric provides the substantially straight glass yarn in the axial or longitudinal direction, the direction of maximum glass yarn lay will be in the axial or longitudinal direction.

Because of the nature of uni-directional glass fabric, the glass yarns lying in the direction of maximum lay will be relatively straight as compared to the glass yarns lying in the direction of minimum glass yarn lay, and also as compared to glass yarn in conventional glass fabrics. In fact, for the purposes of the present invention, in such uni-directional fabrics the small cross yarns in the direction of minimum yarn lay are merely for the purpose of holding the glass yarns in the maximum yarn lay direction together in a side by side arrangement, and while some tensile strength in the peripheral direction may be provided by them it will be understood that it is the helically wound unwoven yarn that is primarily relied upon to provide the desired tensile strength in the peripheral direction. Thus, the term "substantially straight glass yarn lying in the axial or longitudinal direction" will be understood to refer to the glass yarn lying in the maximum lay direction of a uni-directional glass fabric as well as to unwoven glass yarn. Preferably, however, the uni-directional glass fabric

providing the substantially straight glass yarn in the longitudinal direction of the product will be of a weave maintaining at a minimum the possibility of kinks in the yarn in the maximum lay direction. Such a weave is, for example, a satin weave in which the glass yarns in the maximum lay direction pass over at least four cross yarns before interlacing. That is, instead of interlacing with every other cross yarn as is the case with straight weave, the yarns in satin weave interlace at every fifth, sixth, seventh, or eighth etc. cross yarn. Of particular advantageous utility is a uni-directional glass fabric woven in a so-called eight shaft satin weave, that is, where the individual glass yarns pass over seven cross yarns and under the eighth. As indicated, where a uni-directional glass fabric is employed, the yarn from which it is prepared will be as described above and is preferably prepared from continuous glass filaments.

As indicated, in the completed product of the invention, the various glass yarns are impregnated with a resin binder which has been set and hardened. The resin binder is employed for the purpose of holding the various yarns in place and to fill the interstices in and between the yarns. As will appear hereinafter, the various glass yarns are impregnated with the resin in a liquid condition, and the product of the invention is built up from the wet yarn containing the liquid resin. The uncured product is then treated to convert the resin to a hard solid form. Since thermoplastic resins exhibit a tendency to cold flow under stress and since the materials to be treated in the various articles are often at elevated temperatures where thermoplastic resins would soften, a thermosetting resin is employed as the binding medium. By thermosetting resin is meant, as is well known, a resin that under the influence of heat, with or without a catalyst, will harden to a solid infusible, insoluble state. There are a wide variety of such resins such as, for example, the phenol-formaldehydes; urea-formaldehyde; melamine-formaldehyde; furfuryl alcohol; furfuraldehyde; the unsaturated polyester type resins formed by the condensation of an alcohol with a polybasic acid at least one component of which has an unsaturated double bond in an aliphatic group; and the like resins.

Advantageously, from the standpoint of the process, a resin which cures, i. e. becomes converted to the infusible, insoluble state, under relatively low positive pressures, such as less than about 50 p. s. i., is employed. Especially suitable low-pressure thermosetting resins are the furfuryl alcohol resins and the polyester resins in which at least one of the reactants contains an unsaturated double bond in an aliphatic group. For example, the unsaturated bond may be in the polybasic acid component such as when maleic acid or anhydride is reacted with a polyhydric alcohol such as glycerol, ethylene glycol, diethylene glycol, propylene glycol, sorbitol, mannitol, pentaerythritol, polyethylene glycol, and the like. On the other hand, the unsaturated bond may appear only in the alcohol component such as when allyl alcohol is reacted with a polybasic acid such as phthalic acid or anhydride, maleic acid, tartaric acid, citric acid, succinic acid or anhydride, glutaric acid, adipic acid, pimelic acid, suberic acid, sebacic acid, camphoric acid, and the like. Obviously, mixtures of polybasic acids and/or alcohols may be employed; for example, the resins may be prepared by the conjoint reaction of a number of polybasic acids and/or

alcohols of the type described, that is polybasic alcohols and/or allyl alcohol. Examples of such resins are those formed by reacting phthalic anhydride and maleic acid with glycerol, by reacting phthalic anhydride with glycerol and allyl alcohol, and by reacting phthalic anhydride, citric acid, and sebacic acid with ethylene glycol, allyl alcohol, and sorbitol. In preparing these resins, it is often highly advantageous to incorporate therein a small amount of a polymerizable vinyl compound, i. e. a compound containing the vinyl group $\text{CH}_2=\text{CH}-$, to facilitate, by copolymerization, cross linking with the unsaturated bond of the polyester component. Such vinyl compounds are vinyl chloride, vinyl acetate, methyl methacrylate, styrene, and the like. Since these vinyl compounds are present to enhance the thermosetting properties of the resin by facilitating cross linking, the amount employed, while varying widely depending upon the particular components of the resin, will be dictated with such end in view and will not be in such amount as to impart thermoplastic properties to the resin.

The furfuryl alcohol resins and unsaturated polyester type resins as described above are particularly desirable also from the standpoint of other properties possessed by them. These resins in liquid form readily wet the yarn, and in the cured state are particularly tough and resilient, properties which are required by the use intended for the product of the invention. In the cured form, they are also highly resistant to chemical attack by acids, bases, and solvents.

Obviously, regardless of the resin employed, it will be, in the preparation of the product of the invention, in the liquid state to facilitate its impregnation into the glass yarn. The resin may be in liquid form due either to the fact that it is in a low state of polymerization or that it is dissolved in a suitable solvent, or both. Such a resin will be referred to herein as an initial uncured thermosetting resin in liquid form to distinguish it from the cured thermoset or final infusible, insoluble stage in which it appears in the final product. As is well known in the art, various catalysts, whether latent catalysts, that is catalysts which take effect only upon the application of heat, or otherwise may be added to the initial liquid resin to facilitate its subsequent conversion to the final insoluble, infusible stage. With the preferred type of polyester resins described above particularly advantageous catalysts are the organic peroxides such as benzoyl peroxide, and the like.

The yarn whether unwoven or in the form of a uni-directional glass fabric is impregnated with the liquid resin before it is applied to the mandrel and the product is built up while the resin is still in the liquid form. Any method of impregnating the yarn, as is well known, may be employed such as by dipping, or immersing the yarn, or in the case of a uni-directional fabric, by spraying, painting, and the like. Preferably, however, the yarn, and the fabric if used, is impregnated under vacuum to insure that air within the interstices of the yarn is removed and replaced by the liquid resin.

In preparing the product of the invention, the glass yarn, impregnated with the liquid resin, is applied to a suitable form or mandrel which advantageously conforms to the desired inside shape of the product, until the proper thickness is obtained. The yarn will have the liquid resin distributed within its many interstices and upon its

surface so that as the yarn is applied, and with the tension applied to the helically wound yarn very intimate association of the wet yarns is obtained causing the liquid resin to flow filling interstices between the yarns and forming a continuous medium which serves to hold the yarns in place during fabrication, and which, after the resin is cured, provides a compact, solid structure free of voids.

A parting agent, such as petroleum jelly, a layer cellophane, and the like, may be applied to the surface of the mandrel before applying the resin impregnated yarn in order to facilitate the removal of the final cured structure from the mandrel. On the other hand, the mandrel may actually be a hollow metal member which will serve as the inside lining of the article and is an integral part of the final product. In the event a relatively high tensile strength is not required in the axial direction, the resin-impregnated glass yarn is helically wound on the mandrel until there has been built up on the mandrel a layer of closely packed, resin-impregnated glass yarn of suitable thickness. As is more often the case, however, and in accordance with the preferred embodiment of the invention, substantially straight glass yarn is also applied so as to lay in the axial or longitudinal direction. In this case it is relatively immaterial from the standpoint of the product whether the initial layer of glass yarn applied to the mandrel is helically wound yarn or yarn lying in the axial or longitudinal direction. However, from the standpoint of the process, it is preferred to apply several windings of helically wound resin-impregnated yarn as the initial layer. A layer or layers of resin-impregnated glass yarn, either in the form of uni-directional glass fabric, or as unwoven glass yarn, or both, may then be applied in the axial or longitudinal direction, followed by windings of helically wound resin-impregnated glass yarn, and so on until the desired thickness in alternate superimposed layers of taut, helically wound yarn in the peripheral direction and relatively straight yarn in the axial or longitudinal direction, is obtained. It is to be understood that the term "alternate superimposed layers" is not to restrict the structure to single windings of yarn between each layer of axially-directed yarn, for it will be realized that, depending on the strength requirements, each layer of helically wound yarn between the axially-directed yarns may comprise several windings of yarn giving a single layer several yarns in thickness. The exact thickness of the product will depend, of course, upon the use for which the article is intended, and may range from about $\frac{1}{16}$ inch to $1\frac{1}{2}$ inches or more. After the desired thickness is obtained, together with any built-up portions as more fully discussed hereinafter, the laminated structure is subjected to heat, and more often to heat and pressure until the resin is converted to the final infusible, insoluble stage.

Referring further to the application of the helically-wound, resin-impregnated glass yarn in the peripheral direction, it exists in the final product, as stated, in a taut condition. That is to say, there are substantially no kinks in the yarn in the peripheral direction and preferably the yarn is actually under tension in the final structure. This insures that when the article is put into use and high stresses are encountered in the peripheral direction there will be no slipping or give which could cause distortion and ultimate break-down of the article. This tension or taut-

ness is achieved during preparation of the product by applying tension to the resin-impregnated yarn as it is being helically wound on the mandrel. At least sufficient tension will be applied to the yarn to eliminate any kinks that might occur, during winding, and preferably to insure that the helically-wound yarn will retain a small amount of residual tension in the final product. The exact amount of tension applied to the yarn will depend upon the size of the yarn and upon the thickness of the underlying layer of resin-impregnated yarn already built up at the time, since, with respect to the latter, more tension is usually required as the thickness of the underlying layer increases in order to provide a compact structure. However, generally the amount of tensional force applied will range between about 1 and about 5 pounds per yarn. The use of tension in applying the yarn in the peripheral direction also provides, as stated, a more compact structure allowing not only more yarn to be wound in a given space but also sealing in all underlying liquid resin-impregnated yarn including that lying in the axial or longitudinal direction. Similarly when applying the yarn in the longitudinal direction, whether as unwoven glass yarn or as uni-directional glass fabric care should be taken that no significant kinks or wrinkles are present.

As stated previously, the built up structure in the desired thickness is subjected to heat, and more often to heat and pressure, to convert the resin binder into the infusible, insoluble state. Since the article may be formed to the final smooth size on the interior by the use of the mandrel as described, it is not necessary to employ high pressure and an associated molding step to form the final cured article. A convenient method of curing the resin binder is by the vacuum bag method, in which the built up resin-impregnated glass yarn on the mandrel is placed in a gas-impervious bag made from resilient gas-impervious sheeting and vacuum applied. The gas-impervious material may be, for example, polyvinyl alcohol resin sheeting, rubber sheeting, cellophane, polyethylene, polyvinylchloride, and the like. The evacuation of the bag causes a positive pressure due to the atmosphere to be exerted on the structure. This positive pressure in conjunction with an elevated temperature, such as between about 120° F. and about 300° F., facilitates the conversion of the resin to the infusible, insoluble stage. This method of curing the resin also removes any entrapped air in the laminated structure and firmly retains and consolidates the resin in the interstices of the laminated structure. Further external gas pressure may be applied if desired during curing such as by heating the article in an autoclave such as under pressures as high as 50 p. s. i. It will be realized that the exact technique employed in curing the resin binder will depend upon the particular resin employed, and will present no problem to those skilled in the resin art.

The exact amount and proportions of strength-imparting glass yarn applied in the various directions in preparing the article will depend upon the degree of stress or stresses to which the article is to be subjected while in use. Generally, the proportion by weight of helically wound glass yarn in the peripheral direction to the substantially straight yarn in the axial or longitudinal direction will be of the same order as the proportional resultant stresses to be encountered in the wall of the article in the peripheral direc-

tion and in the axial or longitudinal direction when the article is in use. This stress ratio will depend upon the type of application for which the product is intended. For example, in a conduit or spinning bucket, the preponderant proportion, and often substantially all of the stress encountered will be in the peripheral direction in which case the article may be prepared substantially entirely of helically-wound, resin-impregnated glass yarn. In other words, the proportion of helically-wound glass yarn in the peripheral direction may approach 100% while that of the substantially straight resin-impregnated glass yarn in the axial direction may approach 0%. On the other hand, in bowls adapted for use as centrifuge bowls high resultant stresses in the axial direction as well as high resultant stresses in the peripheral direction may be encountered. In fact in some instances as high as about 75% of the stress encountered in such a bowl will be in the axial direction with about 25% in the peripheral direction. In such a case the proportion, by weight, of helically-wound glass yarn may be as low as about 25% with the substantially straight glass yarn in the axial direction amounting to as high as about 75% by weight based on the combined weight of helically-wound glass yarn in the peripheral direction and the substantially straight glass yarn in the axial or longitudinal direction. Normally, however, at least with respect to bowls adapted for use as centrifuge bowls, the proportion by weight of helically-wound glass yarn will range between about 50% and about 80%, and the proportion of substantially straight glass yarn in the axial direction will range from about 20% to about 50%, based on the combined weight of helically-wound glass yarn in the peripheral direction and substantially straight glass yarn in the axial direction. In a preferred form of the product of the present invention, namely a conical centrifuge bowl, the proportion by weight of helically-wound glass yarn in the peripheral direction will range between about 70% and about 80%, and the proportion of substantially straight glass yarn in the axial direction will range between about 20% and about 30%, based on the combined weight of helically-wound glass yarn in the peripheral direction and substantially straight glass yarn in the axial direction.

Since the resin binder is present for the main reason of maintaining the applied glass yarn in position and to provide a dense compact product free of voids, and since the helically-wound glass yarn is applied in a compact manner through the use of applied tension, the major portion, by weight, of the final product will consist of the glass yarn. That is to say the resin binder will make up less than 50% by weight of the article and preferably between about 20% and about 30% by weight.

Referring now to the drawings, Figure 1, as stated, illustrates in a partly sectional view a representative article, namely a conical centrifuge bowl, prepared in accordance with the present invention. As seen in Figure 1, bowl wall 11 of bowl 10, comprises alternate superimposed layers of helically-wound glass yarn 21 in the peripheral direction and substantially straight glass yarn 22 in the longitudinal direction, the latter being provided by uni-directional glass fabric, the maximum yarn lay of which lies in the axial or longitudinal direction, all bonded and maintained in position with a cured thermosetting resin. It will be realized, that due to limi-

tations in drawing, an illustration of the cross-section showing the many windings of the relatively fine glass yarn and the extreme compactness with which the yarn windings are associated with each other and with the unidirectional glass fabrics, is not possible. Similarly it will be realized that the layers of unidirectional glass fabric will vary widely depending upon the strength requirements in the wall of the product. The drawing, however, is sufficient to illustrate this embodiment of the invention when taken in conjunction with the description set forth in this specification. The alternate superimposed layers and the resin may be seen more clearly in Figure 2. As shown in Figure 1, certain built up portions such as 12 which may serve as rims, flanges, and the like, may be provided by merely building up extra masses of resin-impregnated yarn. Since these built up portions do not add to the strength of the entire bowl wall it is relatively immaterial how the mass is built up and it may be built up by continuous extra windings of yarn as in 12, or by alternate superimposed layers of helically-wound, resin-impregnated yarn and uni-directional fabric, the latter providing the substantially straight glass yarn in the longitudinal direction. The ultimate final shape of the exterior as well as of the built up portion 12, and any other members such as threaded hole 14, may be provided by machining the cured laminated structure. Referring to Figure 2, that figure shows a fragmentary perspective view of a portion of wall 11 of bowl 10 in relatively large scale. This figure shows, in greatly enlarged form, the taut helically-wound glass yarn 21 in the peripheral direction, substantially straight yarn 22 lying in the longitudinal direction, and a thermoset resin binder 23 filling the interstices between the yarns. As shown in Figure 2, the substantially straight glass yarn in the longitudinal direction is conveniently provided by a satin weave uni-directional glass fabric in which the direction of the maximum yarn lay is in the longitudinal direction. In place of, or in conjunction with uni-directional fabric it will be understood that unwoven glass yarn may be arranged in the longitudinal direction in a manner more fully explained herein-after. The type of structure shown in Figures 1 and 2 is employed where relatively high tensile strength is required in the axial or longitudinal direction as well as in the peripheral direction. Although the various glass yarns have been illustrated as solid unitary structures it will be realized that in fact they are, as described above, composed of many individual fibres or filaments, and that the resin is distributed within the interstices of the yarn.

Referring to Figure 3, that figure illustrates another typical article prepared in accordance with the present invention, namely a spinning bucket 30 used in the manufacture of rayon and the like. Wall 31 of spinning bucket 30 comprises taut helically-wound, resin-impregnated glass yarn 32. The yarn arrangement in this case may be seen more clearly in Figure 4 which illustrates an enlarged fragmentary view in perspective of a section of wall 31 of bucket 30. As seen in Figure 4 the helically-wound glass yarn 32 lies in a peripheral direction around the bowl wall 31 and is impregnated and maintained in position by cured thermosetting resin binder 33. This arrangement of yarn is adapted for structures in which little tensile strength in the axial or longitudinal direction is required, but in which relatively high tensile strength in the peripheral

direction is required, such as in the case of a conduit or spinning bucket. As was the case with Figure 1, limitations in drawing prevent the illustration of the many windings of the fine yarn that are in fact present and the compactness of their arrangement. In this case also, it will be realized that the yarn is composed of a multiplicity of individual fibres or filaments and that the resin is impregnated into the interstices formed by them. Figures 3 and 4 are sufficient, however, to illustrate this embodiment of the invention when taken in conjunction with the description set forth herein.

Figure 5 illustrates one method of applying the taut resin-impregnated glass yarn in the peripheral direction, and, if desired, the substantially straight, resin-impregnated glass yarn in the axial direction by means of layers of resin-impregnated uni-directional glass fabric. As seen in Figure 5, glass yarn is held on suitable bobbins 41 and 43. It should be understood that any reasonable number of bobbins, and hence yarns, may be employed simultaneously. The bobbins, such as 41 and 43 may be supported on a suitable framework so that the yarn may be unwound from the bobbins. The yarn from bobbin 41, for example, is passed through a trough 44 containing the liquid resin 52. The thus impregnated glass yarn is then passed through pressure rolls 46 which serve to further force resin into the yarn while forcing air and excess resin therefrom. The yarn is then passed over pulley 54 and through yarn-tensioning spring arm 49 to be wound helically, and under tension, upon mandrel 40 rotated on axis 51. Similarly the yarn from bobbin 43 is passed through the liquid resin 52 in trough 44, up through pressure rolls 45 to pulley 47. The resin-impregnated yarn is then passed through yarn-tensioning arm 50 from which it is wound, under tension, on mandrel 40 simultaneously with the yarn from bobbin 41. Form 40 is rotated on axis 51 to helically wind the yarns on the mandrel, spring-tensioning devices 49 and 50 assuring that the yarn will be under sufficient tension to maintain a relatively straight and uninked relation, and preferably residual tension, as it is wound on mandrel 40.

In this manner as much resin-impregnated yarn as desired may be wound on mandrel 40, and, if no substantially straight yarn in the axial direction is required, sufficient resin-impregnated glass yarn may be helically-wound on the form until the desired wall thickness is obtained. Any built up portions needed for rims, flanges, or the like may be provided by merely winding an added mass of resin-impregnated yarn at the point or points on the laminated structure where such built-up portions are desired. However, in the event it is desired to also apply resin-impregnated yarn in the axial direction, winding may be temporarily discontinued after a suitable thickness of helically-wound resin-impregnated yarn is obtained, and, as shown in Figure 5, a piece or pieces of resin-impregnated uni-directional glass fabric 53 is applied with the maximum yarn lay in the axial direction. While the resin-impregnated fabric may be applied in the form of several pieces each cut to cover a section of the circumference, it is preferred to apply the fabric in one piece cut to conform to the circumference of the partially built up structure. During application of the resin-impregnated glass fabric care is taken to avoid wrinkling of the fabric. After the uni-directional glass fabric is applied, additional helical windings of tensioned resin-impregnated

glass yarn may be made in the peripheral direction, followed by the application of additional resin-impregnated uni-directional glass fabric, and so on until the desired thickness is obtained. In this case also, any built-up portions which are to serve as rims, flanges or the like may be formed roughly by building up masses of resin-impregnated yarn or fabric at the places desired.

In Figure 6 is shown a method, which may be used in conjunction with the apparatus shown in Figure 5, for applying alternate layers of substantially straight and unwoven resin-impregnated glass yarn in the axial direction. As shown in Figure 6, a desired number of windings of yarns 63 and 61 may be made, after which winding in the peripheral direction may be temporarily discontinued, while resin-impregnated glass yarn 62 is wound back and forth in the axial direction between selvage pins 63 spaced around the periphery of disks 64 and 65 located at each end of the mandrel to which the layers of resin-impregnated glass yarn are being applied. When a layer of desired thickness has been obtained of resin-impregnated glass in the axial direction, helical winding of the resin-impregnated glass yarn in the peripheral direction may be resumed, and so on, until the desired wall thickness has been obtained. Glass yarn extending beyond the ends of the mandrel in the axial direction around selvage pins 63 may be severed along the edge of the mandrel. It will be realized that the alternate superimposed layers of taut helically-wound glass yarn in the peripheral direction and any substantially straight glass yarn lying in the axial direction will be proportioned by weight as described previously, depending upon the desired proportional stress resistance in the product in the peripheral and axial directions.

The liquid resin-impregnated laminated glass yarn structure prepared as described above may then be subjected to the curing step as described previously, whereby the resin binder is converted into the insoluble, infusible stage. The surfaces of the cured product may be machined to final size and shape in a manner known to the art.

As an illustration of a hollow cylindrical article prepared in accordance with the present invention there was prepared a conical centrifuge bowl 22½ inches in length and having an inside diameter at the small end of 7½ inches and an inside diameter at the large end of 14½ inches. The strength giving wall portion of the bowl exclusive of built-up portions was ½ inch in thickness. The wall was formed of eleven layers of uni-directional glass fabric having an individual thickness of 0.009 inch laminated in alternate and superimposed relation to helically-wound glass yarn. The resin binder employed was an unsaturated polyester type resin formed by reacting a polyhydric alcohol and allyl alcohol with phthalic anhydride and copolymerizing the resulting condensation product with a vinyl compound such as styrene. The liquid resin-impregnated glass yarn structure was then placed within a polyvinyl alcohol resin sheeting bag, and the bag was evacuated exerting a positive pressure of near atmospheric on the laminated structure. The assembly was then heated to 150° F. for about 12 hours, then to 220° F. for about 4 hours and finally to 260° F. for 6 hours. The assembly was then allowed to cool slowly over a period of about 8 hours, following which the cured laminated article was removed from the bag. The cured final product exhibited a yield point strength in the peripheral direction of

approximately 70,000 p. s. i., and a yield point strength in the axial direction of approximately 40,000 p. s. i.

Considerable modification is possible in the selection of the various binders as well as in the technique of fabricating the novel products without departing from the scope of the present invention.

I claim:

1. A centrifugal bowl comprising alternate superimposed layers of taut unwoven glass yarn helically wound in the peripheral direction and substantially straight glass yarn lying in the axial direction, said yarn being impregnated with a thermosetting resin binder in the infusible, insoluble stage.
2. A centrifugal bowl comprising alternate superimposed layers of taut continuous-filament unwoven glass yarn helically wound in the peripheral direction and substantially straight glass yarn lying in the axial direction, said yarn being impregnated with a thermosetting resin binder in the infusible, insoluble stage.
3. A centrifugal bowl comprising alternate superimposed layers of taut, continuous-filament unwoven glass yarn helically wound in the peripheral direction and substantially straight glass yarn lying in the axial direction, said yarn being impregnated with a thermosetting resin in the infusible, insoluble stage, and the proportion by weight of said helically wound glass yarn in the peripheral direction to said relatively straight glass yarn in the axial direction being approximately equivalent to the proportional resultant stress distribution in said directions when said bowl is operated in a centrifugal machine.
4. The product of claim 3 wherein the proportion by weight of said helically wound glass yarn in the peripheral direction is not less than about 25% and wherein the proportion by weight of said substantially straight glass yarn in the axial direction is not greater than about 75%, based on the combined weight of said yarn in said directions.
5. The product of claim 3 wherein the proportion by weight of said helically wound glass yarn in the peripheral direction is between about 50% and about 80%, and wherein the proportion by weight of said substantially straight glass yarn in the axial direction is between about 20% and about 50%, based on the combined weight of said yarn in said directions.
6. A centrifugal bowl comprising alternate superimposed layers of taut unwoven glass yarn helically wound in the peripheral direction and unidirectional glass fabric, the direction of the preponderant glass yarn lay in said fabric being in the axial direction, said yarn and said fabric being impregnated with a thermosetting resin binder in the infusible, insoluble stage.
7. A centrifugal bowl comprising alternate superimposed layers of taut unwoven glass yarn helically wound in the peripheral direction and unidirectional glass fabric, the direction of the preponderant glass yarn lay in said fabric being in the axial direction, said unwoven yarn and said fabric being impregnated with a thermosetting resin binder in the infusible, insoluble stage, and the proportion, by weight, of said helically-wound glass yarn in the peripheral direction to the glass yarn lay in the axial direction being approximately equivalent to the proportional resultant stress distribution in said directions when said bowl is operated in a centrifugal machine.
8. The product of claim 7 wherein the propor-

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tion by weight of said helically wound glass yarn in the peripheral direction is not less than about 25%, and the proportion by weight of the glass yarn lay in said fabric in the axial direction is not greater than about 75%, based on the combined weight of said helically wound glass yarn and glass yarn lay.

9. The product of claim 8 wherein each of said layers of helically-wound, unwoven glass yarn comprises a plurality of layers of a multiplicity of continuous windings of taut, resin-impregnated, unwoven glass yarn wound in the peripheral direction; wherein the proportion by weight of said helically wound glass yarn in the peripheral direction is between about 50% and about 80%, and the proportion by weight of glass yarn lay in said fabric in the axial direction is between about 20% and about 50%, based on the combined weight of said helically wound glass yarn and glass yarn lay.

10. The process of manufacturing a centrifugal bowl which comprises applying alternate superimposed layers of liquid thermosetting resin-impregnated unwoven glass yarn helically wound under tension in the peripheral direction and substantially straight liquid thermosetting resin-impregnated glass yarn in the axial direction to a mandrel, and converting said thermosetting resin to the infusible, insoluble stage.

11. The process of manufacturing a centrifugal bowl which comprises applying alternate superimposed layers of liquid thermosetting resin-impregnated unwoven glass yarn helically wound under tension and liquid thermosetting resin-impregnated unidirectional glass fabric, the preponderant glass yarn lay in said fabric being applied in the axial direction, to a mandrel the outer contour of which conforms to the desired inner surface of said bowl, and converting said thermosetting resin to the infusible, insoluble stage.

12. The process of claim 11 wherein the proportion by weight of said glass yarn helically wound in the peripheral direction to the glass yarn lay in the axial direction is approximately equivalent to the proportional resultant stress distribution to be encountered when the bowl is in operation.

13. The process of claim 12 wherein the proportion by weight of said glass yarn helically wound in the peripheral direction is not less than about 25%, and of the glass yarn lay in the axial direction is not more than about 75%, based on the combined weight of said helically wound glass yarn in the peripheral direction and said glass yarn lay in the axial direction.

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14. A hollow circular article comprising alternate superimposed layers of taut, continuous-filament unwoven glass yarn helically wound in the peripheral direction and substantially straight glass yarn lying in the axial direction, said yarn being impregnated with a thermosetting resin binder in the infusible, insoluble stage, said article containing between about 70% and about 80% by weight of said glass yarn.

15. The process of manufacturing a hollow circular article which comprises applying alternate superimposed layers of continuous-filament liquid thermosetting resin-impregnated unwoven glass yarn helically wound under tension in the peripheral direction and substantially straight liquid thermosetting resin-impregnated glass yarn in the axial direction to a mandrel, and converting said thermosetting resin to the infusible, insoluble stage, said article containing between about 70% and about 80% by weight of said glass yarn.

16. A hollow circular article comprising alternate superimposed layers of taut unwoven glass yarn helically wound in the peripheral direction and substantially straight glass yarn lying in the axial direction, said yarn being impregnated with a thermosetting resin binder in the infusible, insoluble stage.

17. A hollow circular article comprising alternate superimposed layers of taut, continuous-filament unwoven glass yarn helically wound in the peripheral direction and substantially straight glass yarn lying in the axial direction, said yarn being impregnated with a thermosetting resin binder in the infusible, insoluble stage.

18. A hollow circular article comprising alternate superimposed layers of taut unwoven glass yarn helically wound in the peripheral direction and unidirectional glass fabric, the direction of the preponderant glass yarn lay in said fabric being in the axial direction, said yarn and said fabric being impregnated with a thermosetting resin binder in the infusible, insoluble stage.

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