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ROVING IMPREGNATOR FOR MAKING LOW-VOID FILAMENT WOUND ARTICLES

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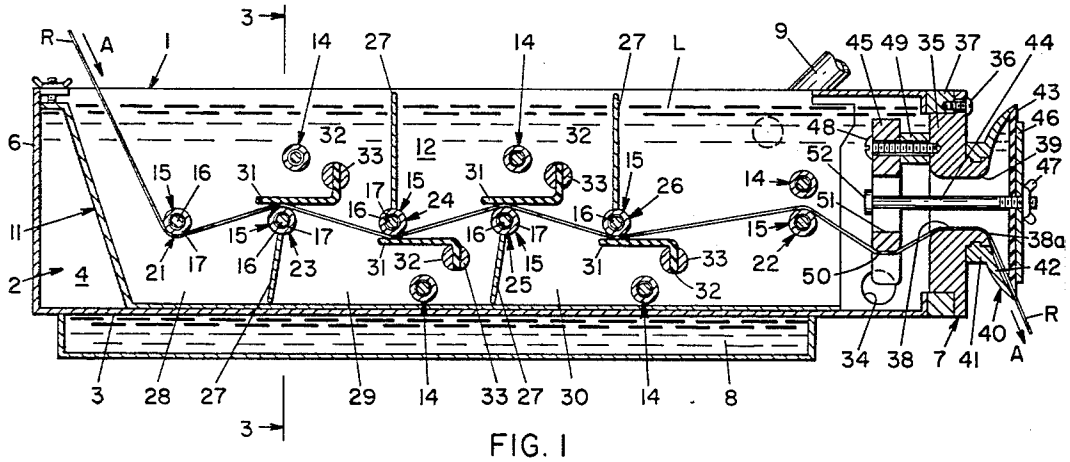


FIG. 1

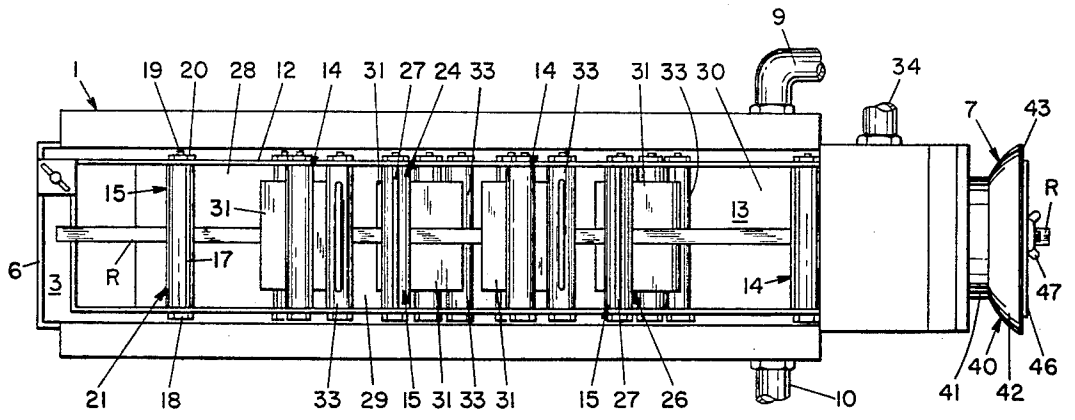


FIG. 2

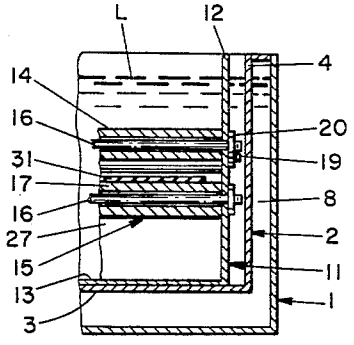


FIG. 3

JAMES T. PAUL, JR.
INVENTOR.

BY Edward L Bell

ATTORNEY

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ROVING IMPREGNATOR FOR MAKING LOW-VOID FILAMENT WOUND ARTICLES

James T. Paul, Jr., Cooper Farms, Wilmington, Del., assignor to Hercules Incorporated, Wilmington, Del., a corporation of Delaware

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ABSTRACT OF THE DISCLOSURE

A roving impregnating device comprising a tank filled with resin having an exit for the roving located below the normal liquid operating level and a plurality of submerged guides defining a tortuous path for the roving and a flexible wiper associated with each guide for compressing the filaments against the guide.

The present invention relates to a roving impregnator for use in apparatus for making low-void filament wound articles.

The filament wound articles to which the present invention relates have a wall consisting of wound filaments or fibers and a binding material. The fiber used is generally in the form of roving and is of glass or other material that is characterized by high tensile strength and light weight or, stated differently a very high strength-to-weight ratio. The binding material, is a thermosetting resin, such as an epoxy polymer, which impregnates the fiber windings and, when cured, becomes permanently set and thus binds the wound fibers into a self-supporting article. These articles are designed primarily for use in application requiring light weight as well as the capacity for withstanding high pressure or other stresses, such applications being, for example, a rocket case or the boom of a "cherry picker," or the capacity for withstanding high electrical stresses as required for use in circuit breaker tubes.

In making filament wound articles, one method that has been widely used commercially is the so-called wet-winding process wherein the fiber in the form of a roving is first passed through a supply of the resinous binding material, which may be any suitable thermosetting resin that is liquid at room temperature and can be cured at temperature within the tolerance of the fiber. The fiber or roving is thus wetted with the binding material and is thereafter wound, usually under tension, on a mandrel in accordance with a predetermined pattern. The binding material is then cured, after which the self-supporting article is separated from the mandrel.

Filament wound articles produced by the usual wet-winding process may generally be characterized as including voids in the windings of between four and ten percent by volume, the voids being a local absence of binding material between adjacent filaments. These voids have significant adverse effects upon the physical properties of the article and particularly upon the interfilamentary shear strength, that is, shear strength longitudinally between adjacent filaments, which strength can be increased by twenty-five to one hundred percent by reducing the voids from the normal level to substantially zero.

In addition to increasing the inter-filamentary shear strength, the reduction of voids in a filament wound article also increases the dielectric strength thereof, thereby adapting the same for use in applications such as in the circuit breaker tubes of a power distribution system where electrical properties as well as high strength,

light weight, inertness and/or thermal properties are important.

Another significant characteristic of a low-void filament wound article is its optical clarity. When the number of voids is reduced to a minimum, and assuming a compatible selection of glass fiber and binding material, the transparency of the article is greatly improved. The article is thus rendered useful for applications such as pressure tanks where seeing into the tank is important.

Briefly, voids in filament wound articles are caused for example by air that is trapped between fibers or is adhered to the surface of the fiber, or is encapsulated or dissolved in the resin, or through errors in the winding pattern or about inserts such as nozzle elements, or by improper handling of the fiber of the wound article. A more thorough discussion of the source of voids in a filament wound article is presented in applicant's co-pending application Ser. No. 578,605, filed Sept. 12, 1966, to which reference is made.

Prior efforts to eliminate voids in filament wound articles have included winding the roving under tension to compact the windings and thus force out the air, heating the resin to reduce the amount of air that is dissolved in the resin and to facilitate the escape from the resin of the air pumped into it by the "rope-pump" effect, and curing the wound article under pressure to reduce the size of the bubbles by physically compressing them and by increasing the solubility of the air in the resin to dissolve the air from the bubbles. Another approach has been to mount the entire winding apparatus, including the roving impregnator, in a vacuum chamber. In the method disclosed and claimed in applicant's above noted prior application Ser. No. 578,605, very low-void filament wound articles are produced by impregnating the roving under vacuum, thereby providing a substantially void-free roving that is wound into the article. A further method of producing low-void filament wound articles is disclosed and claimed in applicant's prior application Ser. No. 578,605, filed Sept. 12, 1966, which method involves a dry wound article that is subsequently impregnated under vacuum.

In accordance with this invention, it has been found that substantially void-free filament wound articles can be produced by the use of a series of guide members defining a tortuous path for the roving and complemental wiping members acting upon the roving as it passes over the guide members to wipe the encapsulated or entrained air from the surface thereof, and to collapse the same and thereby force or squeeze from the roving the air trapped therein. There is also provided means such as baffle members defining a series of resin compartments with the wiping members located at the input of the compartments, and with the resin input at the roving output end of the impregnator whereby there is no free flow of resin in the impregnator from the roving input to the roving output ends and the resin having the most entrained air is thus isolated at the roving input end of the impregnator. It is also within the contemplation of this invention that the resin will be heated to facilitate the release and escape of the air from the resin.

In accordance with the above, the objects of this invention are to provide roving impregnating means for making low-void filament windings, which means is relatively inexpensive, simple in construction, easy to operate and to maintain, and will effectively wet the roving with the binding material or resin while removing most of the air therefrom whereby, upon winding the wet roving into an article, there is produced a substantially void-free article.

Further objects of this invention will be apparent from an understanding of the preferred embodiment of the invention hereinafter described with reference to the accompanying drawings, in which:

FIG. 1 is a vertical sectional view substantially longitudinally of an impregnator embodying this invention.

FIG. 2 is a plan view of the impregnator of FIG. 1.

FIG. 3 is a fragmentary section view taken substantially on the line 3—3 of FIG. 1.

With reference to the drawings, there is illustrated a roving impregnator 1 comprising a tray-like base 2 open at the top and including a bottom wall 3, opposed side walls 4 and 5, and an end wall 6. The end wall 6 is at the roving input end of the impregnator while the opposite end is closed by an exit seal 7 that is more fully described hereinafter. The base member 2 defines a resin chamber that is adapted to be filled with resin to a normal operating level L. The bottom wall 3 and side walls 4 and 5 are enclosed within a heating jacket 8 to which a heating fluid such as water or oil is fed by an inlet 9 and from which it is exhausted by an outlet 10. The heating jacket 8 is preferably baffled to provide for a uniform flow of the heating fluid through the jacket and thus provide a uniform heating of resin in the base 1.

Mounted within the base 1 is a unit 11 comprising a pair of opposed supporting plates 12 that are held in spaced parallel relation by a bottom wall 13 and by a plurality of transverse spacing rods 14 and a plurality of guide members 15 which are also in the form of rods that are arranged transversely of the unit 11. Each of the rods 14 and guide members 15 comprise a bolt 16 having the shank portion thereof surrounded by a spacer sleeve 17 and having at the opposite ends thereof a head 18 and a threaded portion 19 that receives a nut 20. The unit 11 is designed to fit in the base 1 only with sufficient clearance to permit the same to be introduced into and to be withdrawn from the base 1 with reasonable facility.

The guide members 15 include an input guide 21 adjacent to the end wall 6, an output guide 22 adjacent to the exit seal 7, and a series of intermediate guides 23, 24, 25 and 26. The guide members are staggered from a straight line between the guides 21 and 22 whereby the roving R is threaded under the input guide 21, over the guide 23, under the guide 24, etc., and thereby moves along a tortuous path through the impregnator as it is deflected by the roving engaging edge of each guide. A baffle 27 is secured as by brazing to each of the sleeves 17 of each of the intermediate roving guides 23–26 and extends radially therefrom in the direction substantially diametrically opposed to the filament engaging edge. The baffles 27 are each substantially as wide as the unit 11. The baffle 27 on the guide 23 depends substantially to the bottom wall 13 whereby the unit 11 is substantially closed transversely below the guide 23 to define a resin compartment 28. The baffle 27 on the guide 25 also depends substantially to the bottom wall 13 of the unit to define resin compartments 29 and 30. The guides 24 and 26 are located within the compartments 29 and 30, respectively, and the baffles 27 thereon extend upwardly to above the operating level L of the resin therein.

Cooperating with each of the intermediate guides 23, 24, 25 and 26 is a resilient wiper 31 which may for example be a rubber flap and is substantially as wide as the unit 11. Each of the wipers 31 is mounted with one edge thereof received in a slot 32 in a supporting means or rod 33 that extends transversely of the unit 11 on an axis substantially parallel to the axes of the guides 21–26 and is secured at its ends to the side walls 12 of the unit in any suitable fashion.

Considered in the direction in which the roving R moves, the rods 33 are all located downstream from the guide with which the wiper 31 thereon cooperates. At the same time, the slots 32 are all substantially vertical with the exit thereof generally at the same elevation as the filament engaging edge of the respective guide, that is, either the uppermost or lowermost edge of the guide, depending upon whether the yarn passes over or under the individual guide. In its operative position, each of the wipers is deflected at substantially a right angle from the plane defined by the slot 32, which would be the normal relaxed condition of the wiper into engagement with the filament engaging edge of the respective guide. Being resilient, when a wiper is deflected in this manner, it bears against the respective guide to exert pressure on roving running between the element and the guide to collapse the same and thereby work air from the roving. With the wipers 31 arranged to extend generally in the direction opposed to the direction of travel of the roving R as illustrated, friction between the roving and a wiper tends to increase the pressure of the element against the guide. The rods 33 are angularly adjustable to effect a greater or lesser deflection of the wipers 31, thereby increasing or decreasing the pressure of the wipers on the respective guides and thus upon the roving. To a certain extent, the tension on the roving can be controlled in this manner.

In operation, the impregnator 1 is filled with resin to the level L as through a resin inlet 34. When filled, the baffles 27 on the guides 24 and 26 extend above the level L of the resin. The roving R, which is pulled through the impregnator in the direction indicated by the arrow A, passes from a supply, under the input guide 21, then successively over and under the intermediate guides 23, 24, 25 and 26, over the outlet guide 22, and finally exits from the impregnator through the seal 7. At each of the guides, the tension in the roving tends to collapse the same against the guide and thereby work the trapped air from between the filaments of the roving and to wipe the air from the surface thereof. At the same time, the wiper element 31 associated with each of the intermediate guides, bears against the roving as it passes between the element and the guide to assist in removing the air. The working of the roving at the successive intermediate guides acts to remove the residue of the air that was not removed at the preceding guide members. While there are illustrated four intermediate guides, this number is not critical. A larger or smaller number of guides could be used, depending upon the specific operating conditions, such as the viscosity of the resin which determines how fast the removed air can escape from the resin and thus how much of the air is carried into the successive resin compartments. The important factor is that, when the roving arrives at the outlet guide 22, it should be substantially free of air.

It will be apparent that the greatest portion of the air is removed in the compartment 28, that is, by the input guide 21 and the intermediate guide 23. Because of this and because of the "rope-pump" action of the roving as it enters the resin, the resin in the compartment 28 becomes thoroughly contaminated with air. This contaminated resin is, however, to a large extent restricted to the chamber 28 by the baffles 27 on the guides 23 and 24. The baffle 27 on the guide 23 limits migration of the resin from the compartment 28 to the compartment 29 to a path over the wiper 31 and its supporting rod 33. In moving along this path, the contaminated resin passes close to the resin surface so that escape of the air from the resin is facilitated. The baffle 27 on the guide 24 then prevents the contaminated resin from moving along the resin surface to the compartment 29.

The baffles 27 on the guides 25 and 26 function in the same manner as those on the guides 23 and 24 to prevent the air removed from the roving R in the compartment 29 from migrating into the compartment 30.

With the arrangement as above described, it will be seen that the air that is worked from the roving at each of the intermediate guides can rise directly to the resin surface and escape. At the same time, the contaminated resin is substantially confined to the surface of the impregnator where escape of the air is facilitated while the roving itself moves generally along the bottom of the impregnator in the less contaminated resin. The "rope-pump" action of the roving is also confined to the compartment 28.

As hereinbefore mentioned, escape of the air from the resin can be accelerated by reducing the viscosity of the resin by heating. Migration of the contaminated resin forward to the output end of the impregnator can also be

inhibited by placing the resin inlet through which the make-up resin is introduced at the output end of the impregnator. This make-up resin, which can be introduced into the compartment **30** either by hand at intervals, or automatically by a level-maintaining device (not shown), is substantially air-free. From the compartment **30**, the make-up resin then flows under the wiper **31** at the guide **26**, over the wiper **31** at the guide **25**, under the wiper **31** at the guide **24**, and over the wiper **31** at the guide **23**. In this manner there is established a flow of the air-free make-up resin from the compartment **30** to the compartment **28**, which insures that the roving R at the output end of the impregnator engages only air-free resin and also tends to flush the contaminated resin back toward the input end of the impregnator.

The exit seal **7** comprises a body **35** that is secured as by screws **36** to a fastening ring **37** that is in turn secured to the output end of the base member **2**. The body **35** has a central opening, the annular wall of which acts as a roving guide surface **38** and which includes smooth shoulders leading onto and off the same, and including a roving guide edge **38***a*.

The body **35** includes a tubular mounting section **39** extending axially thereof on the output side. An annular or roughly dish-shaped inner flap member **40** is mounted on the section **39** by means of a hub **41** that surrounds the section **39**. The inner flap member **40** also includes an annular flange **42** extending outwardly from the hub **41** that cooperates at its periphery with the edge of an outer flap member that is in the form of a disc **43** carried by a stud **44** extending from a mounting member **45** axially through the opening defined by the surface **38**. The disc **43** is reinforced by a supporting disc **46** and is held on the stud **44** by a wing-nut **47**.

The mounting member **45** is secured in spaced relation to the body **35** by screws **48** and spacer sleeves **49**, and is formed with a plurality of guide slots **50** for guiding a plurality of separate and individual rovings from the guide **22** to the guiding surface **38**. The stud **44** extends through a slot **51** in the member **45** from a bar **52** secured to the member **45** and spanning the slot **51**.

The flap members **40** and **43** are designed primarily to permit escape of the roving R from the impregnator while preventing escape of the resin. In addition, the flap members are also designed to avoid excessive wiping of the resin from the roving that would result in an inadequate supply of resin in the final article. A further purpose of the flap members **40** and **43** is to prevent air from being drawn in at the sides of the roving, which air can be encapsulated and carried on the surface of the roving into the wound article. For these purposes, the flap members are designed to provide a very light wiping contact on the roving and to conform very closely to the periphery of the roving and thereby to avoid any opening between the same at the edges of the roving. Accordingly, the flap members **40** and **43**, and particularly the outer flap member **43**, are formed of a very light flexible material such as a thin sheet of rubber. The supporting disc **46** serves to maintain the flap member **43** in operative position relative to the flap member **40** against the pressure head of the resin. The lead of the roving from the edge **38***a* through the meeting edges of the flap members **40** and **43** is substantially along a line passing straight through the meeting edges and thus imposing a minimum deformation of the flap members which would tend to separate the meeting edges.

What I claim and desire to protect by Letters Patent is:

1. An impregnator for use in a winding machine for making low-void filament wound articles, said impregnator comprising a resin chamber adapted to be filled with resin to an operating level, an exit from said chamber below said operating level and means for sealing said exit against resin while providing for passage of roving therethrough, a plurality of guides below said operating level defining a tortuous path through said resin chamber to said exit, and a plurality of wipers each of which is adapted to cooperate individually with one of said guides and comprises a flexible and resilient member mounted relative to the filament engaging surface of the respective guide and deflected from its relaxed condition into resilient engagement with said filament engaging surface, whereby said member will wipe and collapse against said filament engaging surface a roving running between the member and the filament engaging surface of the guide.

2. An impregnator in acocrdance with claim **1** in which said guides are arranged whereby the tortuous path defined by the same is generally horizontal.

3. An impregnator in accordance with claim **2** in which said guides comprise guide members disposed horizontally and extending transversely of said resin chamber.

4. An impregnator in accordance with claim **3** in which each of said wiper elements are mounted on supporting members disposed substantially parallel to said guide members and downstream from the respective guide member in the direction in which the roving advances toward said exit and at substantially the same elevation as the filament engaging surface of the respective guide member.

5. An impregnator in accordance with claim **1** in which said resin chamber is divided by transverse baffle means into a plurality of individual resin compartments.

6. An impregnator in accordance with claim **5** in which said transverse baffle means comprises depending baffle plates depending from said guide members.

7. An impregnator in accordance with claim **6** in which said depending baffle plate depends from alternate guide members and there is provided a baffle plate upstanding from an intermediate guide member.

8. An impregnator in accordance with claim **1** in which said resin chamber is provided with a resin inlet at the end thereof adjacent to said exit.

9. An impregnator in accordance with claim **1** having heating means on said resin chamber for heating resin therein.

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WALTER A. SCHEEL, Primary Examiner

J. P. McINTOSH, Assistant Examiner

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