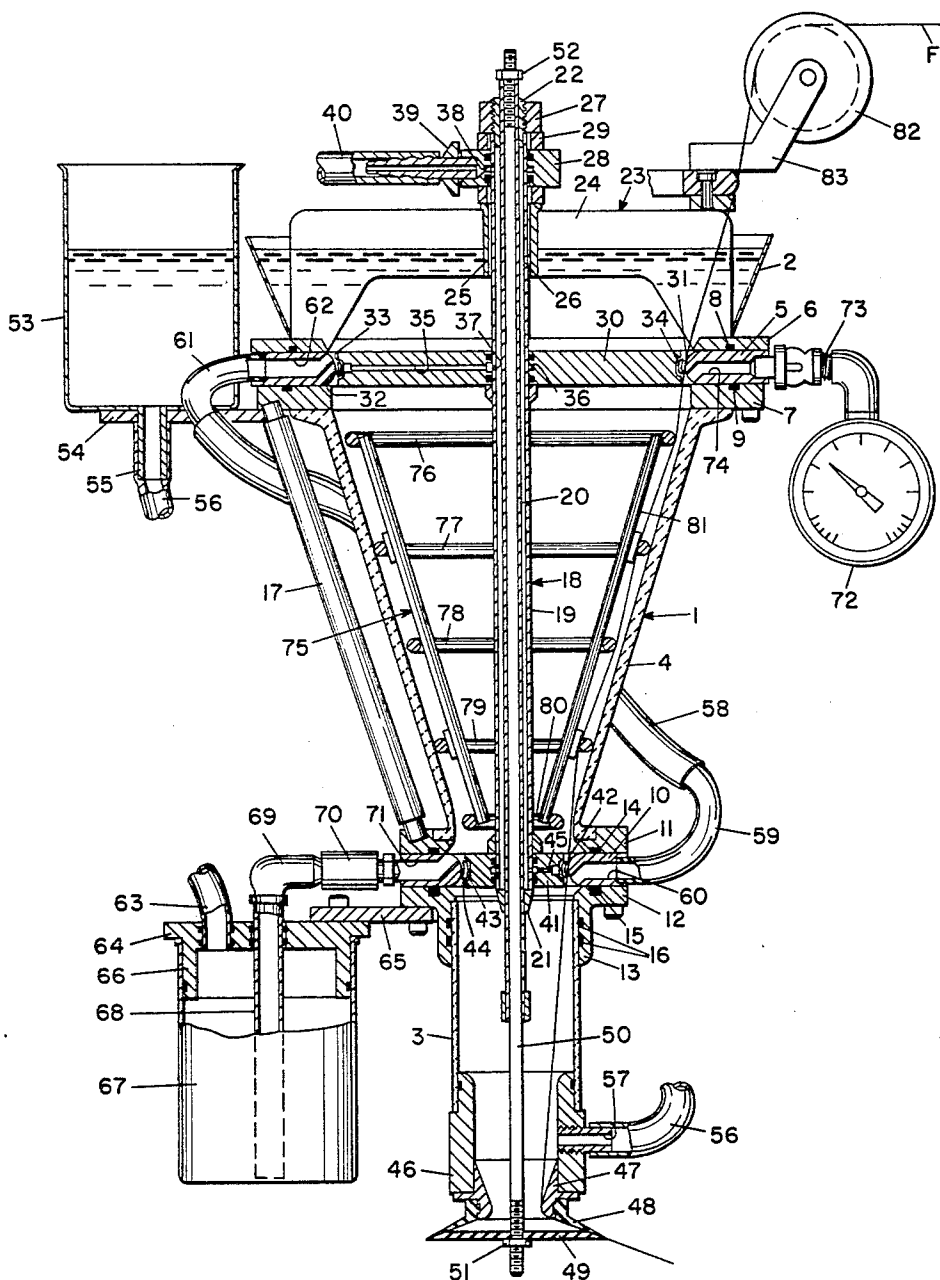


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B. E. METZ ET AL
 ROVING IMPREGNATING APPARATUS FOR USE IN MAKING FILAMENT
 WOUND STRUCTURES
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ROVING IMPREGNATING APPARATUS FOR USE IN MAKING FILAMENT WOUND STRUCTURES

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10 Claims

ABSTRACT OF THE DISCLOSURE

This invention relates to a roving impregnating apparatus for use in making low-void filament wound structures, which apparatus comprises a housing divided horizontally into three parts comprising an upper and a lower resin reservoir and a vacuum chamber intermediate the reservoirs, and seals between the upper reservoir and the vacuum chamber, between the vacuum chamber and the lower reservoir, and at the exit of the lower reservoir providing for passage of the filament while preventing passage of the resin, the exit seal being designed to avoid encapsulating air in the resin and depositing the encapsulated air on the surface of the filament.

This application is a continuation-in-part of our prior application Ser. No. 665,089, filed Sept. 1, 1967 and now abandoned.

The present invention relates to apparatus for use in making filament wound structures and particularly to apparatus for impregnating the filaments with resin prior to winding and under conditions that will remove air from the filaments, which air would cause voids in the filament wound structure.

The filament wound structures to which the present invention relates have a wall consisting of wound filaments and a binding material. The filaments may be glass fiber 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 may be any suitable resin, such as an epoxy resin, that is liquid at room temperature and curable at a temperature within the tolerance of the filaments, which resin impregnates the wound filaments and, when cured, becomes permanently set and thus binds them into a self-supporting structure. These structures are designed primarily for use in applications requiring light weight as well as the capacity for withstanding high pressures or other stresses, such applications being for example a rocket case or the boom of a "cherry-picker." Other applications of such articles are in uses involving high electrical stresses, such as in circuit breaker tubes.

In making filament wound structures, one method that has been widely used commercially is the so-called wet-winding process wherein the filaments in the form of a roving are first passed through a supply of the resinous binding material. The filaments are thus wetted with the binding material and are thereafter wound, usually under tension, on a mandrel in accordance with the predetermined pattern. The binding material is then cured, after which the wound structure is separated from the mandrel, leaving a self-supporting structure having walls consisting of the wound filaments bound together by the hardened binding material.

In the co-pending patent application of J. T. Paul, Ser. No. 578,605, filed Sept. 12, 1966 and assigned to the same assignee as the present application, there is disclosed an apparatus and method for producing filament

wound articles by the so-called wet-winding process. The invention in this prior application relates to reducing the number and volume of gaseous voids in a filament wound structure produced by the wet-winding process by impregnating the filaments with the resinous binding material under vacuum whereby air within the filaments or on the surface of them, or encapsulated or dissolved in the binding material, is removed. This air, if not removed, finds its way into the wound structure where it tends to produce voids which materially reduce the strength of the structure, particularly the interfilamentary shear strength and the dielectric strength, and to reduce the transparency of the structure.

The objects of this invention are to provide a filament impregnating device for producing low-void windings in a wet-winding process, which device is relatively compact and capable of being mounted on and movable with the traverse mechanism of the usual winding machine for making filament wound structures with a minimum of lateral projection and while providing favorable filament lead angles and filament band width control and a smooth flow of the filaments therethrough, and which device is simple and inexpensive to manufacture, maintain and operate.

In accordance with this invention, the above objects have been attained by the use of a single unit that is divided horizontally into an upper and lower resin reservoir and an intermediate vacuum chamber. The means for dividing the unit are plates that are carried by a vertical support centrally of the housing, which plates are sealed relative to the housing by a fluid tight seal that provides for resin-lubricated passage of the filaments therethrough. At the same time, the exit from the lower resin reservoir is provided by a pair of resilient flaps that conform to the cross section of the exiting filaments without an opening at the sides thereof that would permit air to be drawn into the resin.

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

FIG. 1 is a vertical sectional view of a filament impregnating device embodying the invention.

With reference to the drawings, the present invention is illustrated as embodied in an impregnator comprising a housing generally indicated at 1 and comprising an upper resin reservoir 2, a lower resin reservoir 3, and a vacuum chamber 4 between the two reservoirs. Between the upper reservoir 2 and the vacuum chamber 4 there is mounted an annular sealing ring 5 that is clamped between a pair of annular clamping rings 6 and 7, which are secured respectively to the reservoir 2 and the vacuum chamber 4, and which have O-rings 8 and 9 interposed between the faces thereof that abut the sealing ring 5 to provide a fluid-tight connection. An annular sealing ring 10 similar to the ring 5 is interposed between the lower reservoir 3 and the vacuum chamber 4, the ring 10, like the ring 5, being clamped between a pair of annular clamping rings 11 and 12. The clamping ring 11 is secured to the bottom of the vacuum chamber 4 while the clamping ring 12 is formed with a depending sleeve 13 that receives the upper end of the lower reservoir 3. O-rings 14 and 15 are interposed between the abutting faces of the sealing ring 10 and the clamping rings 11 and 12. A pair of O-rings 16 may also be used to provide a fluid-tight seal between the sleeve 13 and the lower reservoir 3. In order to provide for visibility into the vacuum chamber 4, it may be formed for example of a transparent material such as plastic, in which case it may be advisable to provide a plurality of supporting rods 17, e.g., three, extending between the clamping rings 7 and 11.

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Arranged axially of the housing 1 is a hollow support generally designated at 18 and comprising an outer tube 19 and an inner tube 20 co-axially of the tube 19 and having an external diameter smaller than the internal diameter of the outer tube 19 to provide an annular air space or conduit between the same. The two tubes 19 and 20 are secured together and the annular air spaces between them is closed by a collar 21 at the bottom of the tube 19 and by an externally threaded collar 22 at the top of the tube 19. The support 18 is suspended co-axially of the housing 1 by a spider 23 comprising a plurality of vertically disposed planar legs 24, e.g., four, resting at their ends on the clamping ring 6 and radiating from a hub 25 that has a central bore 26 through which the support 18 loosely extends. To position the support 18 vertically in the bore 26 there is a nut 27 threaded onto the collar 22. In the illustrated embodiment of the invention there is a collar 28 and a pair of washers 29 on the support 18 between the nut 27 and the hub 25, so that the nut 27, in effect, abuts against the top of the hub 25 to act as an adjustable stop for limiting the downward movement of the support 18 relative to the hub 25.

The support 18 carries a plate 30 arranged normal to the axis of the support and disposed endwise of the support in the plane of the sealing ring 5. The plate 30 conforms in outline to the inner or sealing edge 31 of the sealing ring 5 and is slightly smaller than the opening defined by the edge 31 of the sealing ring 5. The plate 30 is formed with a channel 32 in the sealing edge 33 thereof, that is, the edge opposed to the sealing edge 31 of the ring 5. An inflatable tube 34, that may for example be of rubber or other suitable elastomer, is mounted in the channel 32 and is adapted to be inflated by air under pressure that is introduced into the same from a bore 35 in the plate 30. The bore 35 communicates with the annular air space between the tubes 19 and 20 through a channel 36 in the plate 30 and a bore 37 in the tube 19. Air under pressure is introduced into the annular space between the tubes 19 and 20 through a bore 38 in the collar 28, which bore communicates at its inner end with the annular space through a channel in the collar 28 and an aperture in the tube 19, and at its outer end with a hose fitting 39 that is in turn connected by a hose 40 to a source of air under pressure. The plate 30, which constitutes the bottom wall of the upper resin reservoir 2 thus has the edge thereof sealed against the sealing ring 5 in a manner that is fluid-tight but permits the passage of filaments through the seal.

The support 18 carries a second or lower plate 41 that is opposed to the sealing edge 42 of the sealing ring 10. Except for size, the plate 41 is in all respects similar to the first or upper plate 30 and includes a channel 43 in its sealing edge and in which is mounted an inflatable tube 44 that is connected to a bore 45 that is in turn connected to the annular air space between the tubes 19 and 20 through a channel in the plate 41 and an aperture in the tube 19.

An advantage of an inflatable tube for the resin seal is that, coupled with the loose mounting of the support 18 on the hub 25, there is no alignment problem. The inflatable seal also is readily deformable to permit the filaments to pass and, with the filaments pre-wetted by resin in the upper reservoir 2, they are lubricated and will pass between the tube and the sealing edge of the sealing ring with a minimum of abrasion.

A sleeve 46 is secured to the bottom of the lower resin reservoir 3 and in turn carries a filament eye or guide 47 formed of a wear-resistant material. The bottom of the reservoir 3 is closed by a pair of cooperating flap members including an annular flap member 48 mounted on the guide 47 and a disc-like flap member 49 that is mounted upon the lower end of a rod 50 mounted for endwise movement in the inner tube 20 of the support 18. The flap member 48 extends outwardly and downwardly

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and is adapted to engage the flap member 49 at the periphery thereof. Engagement of the flap members at their lips or outer edges is adjustable by adjusting the rod 50 vertically, and for this purpose, the flap member 49 rests at its center on a stop 51 on the rod 50. Vertical adjustment of the rod 50 in the tube 20 is provided by a nut 52 threaded upon the upper end of the rod and cooperating with the top of the tube 20.

Resin is introduced into the lower reservoir 3 from a resin supply 53 mounted upon an arm 54 that may be an extension of the clamping ring 7 and having a depending drain tube 55 that is connected by a conduit 56 to a fitting 57 in the sleeve 46 and communicating with the interior of the reservoir 3. The resin supply to the upper reservoir 2 comprises a conduit 58 connected at its lower end to a fitting 59 in a bore 60 in the lower sealing ring 10 and communicating with the interior of the lower reservoir 3. At its upper end, the conduit 58 is connected to a fitting 61 in a bore 62 in the upper sealing ring 5, which bore 62 communicates with the interior of the upper resin reservoir 2.

For drawing a vacuum on the vacuum chamber 4, there is provided a vacuum line 63 connected to a cap 64 carried by an arm 65 extending laterally from the clamping ring 12. The cap 64 has a depending sleeve 66 that is adapted to receive a cup 67 held thereon by friction and vacuum. A tube 68 depends from the cap 64 into the cup 67 and is open adjacent to the bottom of the cup. Above the cap 64, the tube 68 is connected by an elbow 69 to a fitting 70 communicating with a bore 71 in the lower sealing ring 10 and communicating with the interior of the vacuum chamber 4. Thus, a vacuum drawn by the line 63 evacuates the cup 67, which in turn evacuates the chamber 4 through the tube 68, elbow 69, fitting 70 and bore 71. At the same time, resin carried into the vacuum chamber 4 as by the filaments, drains through the same path into the cup 67 which can be periodically removed and emptied.

Vacuum in the chamber 4 can be indicated by a gauge 72 connected to the chamber 4 by a line 73 that communicates with a bore 74 in the sealing ring 5, which bore in turn communicates with the vacuum chamber 4.

Within the vacuum chamber 4, there is a cage-like structure 75 comprising a series of five rods, 76, 77, 78, 79 and 80, which are bent to conform to the configuration of the wall of the chamber at about equally spaced elevations along the wall, and are held in assembled relationship by vertical rods 81. The intermediate rods 77 and 79, that is the rods intermediate the middle rod 78 and the upper and lower rods 76 and 80, conform to the curvature of the wall of the chamber 4 at the selected elevation while the upper, middle and lower rods 76, 78 and 80 are slightly smaller than the wall of the chamber 4 at the selected elevation so that they will be spaced inwardly from the wall of the chamber 4.

A roller guide 82 is journaled on a bracket 83 that is mounted on a bar secured for example to the legs 24 of the bracket 23.

In operation, a bundle of filaments F are directed from a source over the roller guide 82 into the upper resin reservoir 2 and through the seal between the tube 34 and the sealing edge 31 of the sealing ring 5, and thus into the vacuum chamber 4. The filaments are wetted with resin in the reservoir 2 and are thus lubricated to facilitate passage of the same through the seal. In the vacuum chamber 4, the air in the interfilamentary spaces in the bundle of filaments and on the surface of the filaments, as well as the air that is dissolved in or encapsulated by the resin is drawn off. At the same time, working the filaments over the rods 76, 77, 78 and 79 helps particularly to collapse the voids within the bundle of filaments and thus helps to remove the trapped air.

At the bottom of the vacuum chamber, the bundle of filaments passes through the seal between the sealing edge 42 and the tube 44 into the lower resin reservoir 3. The

reservoir 3 is completely filled with resin under atmospheric pressure so that any voids in the bundle of filaments are collapsed. The bundle of filaments then passes out of the resin reservoir 3 between the flaps 48 and 49. The flaps 48 and 49 are designed to permit the bundle of filaments to be withdrawn without permitting the escape of resin from the reservoir 3 at the opening through which the filaments are passing. For this purpose, the flaps are sufficiently rigid to resist the head of the resin in the reservoir but are tapered at the edges thereof so that the edges are flexible enough to follow the cross section of the bundle of filaments without an open space between the two flaps at the edges of the bundle. In a conventional installation, the entire unit would be mounted upon a traverse mechanism that is driven back and forth relative to a rotating mandrel so that upon leaving the flaps 48 and 49, the filaments are deposited upon the mandrel in accordance with a pattern that is determined by the drive for the traverse mechanism relative to the rotation of the mandrel.

In the usual manner, with the bundle of filaments travelling at a relatively high speed into the upper reservoir 2, a considerable amount of air is entrained with the filaments and thus carried into the resin in the reservoir. The resin is thus worked to a froth, the degree of frothing varying with the viscosity of the resin. The air is however limited to the reservoir 2 since, as soon as the filaments pass through the seal at the tube 34 and into the vacuum chamber 4, it is drawn off. In the lower reservoir 3 there is no entrained air carried into the resin by the filaments and the resin is clear.

The lower reservoir 3 is completely filled with resin from the plate 41 to the flap 49 and is kept filled automatically by resin from the supply 53 through the conduit 56 flowing under the head imposed by the elevation of the supply 53. From the lower reservoir 3, the resin is delivered to the upper reservoir 2, through the conduit 58 and will seek a level corresponding to the level of the resin in the supply 53.

The flap members 48 and 49 constitute seal means for closing the bottom of the reservoir 3 while providing for the exit of the bundle of filaments F from the reservoir 3 to the atmosphere. One of the primary advantages of the flap members 48 and 49 is that there is no encapsulated air deposited on the surface of the filaments as they exit. Normally, a rapidly-moving bundle of filaments acts in the nature of a rope pump to entrain air. In the atmosphere, the moving air is not encapsulated and does not become attached or adhere to the surface of the filaments. However, at the exit point between a pair of planar-like sealing elements, the movement of the filament bundle results in a flow pattern somewhat in the nature of vortices at the opposite sides of the filaments between the sealing elements. At this point, air is thus encapsulated in the resin and this encapsulated air in turn attaches to the surface of the filaments and is carried into the structure being wound. Because the lead of the filament is continuously changed during winding and because of other considerations such as threading, it is difficult to provide an effective exit means in a form such as a closely fitting tube, which conforms to the periphery of the filament bundle and thus avoids encapsulating air at the exit. The flap members 48 and 49 form a generally extended and substantially acute angle whereby turbulence thereat is inhibited and the filaments passing therethrough are substantially enclosed by the molding of the deformable flap member over the same and are in effect floated into the atmosphere on a smoothly flowing stream of resin which avoids despositing air at the surface of the filaments as they exit.

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

1. A device for impregnating filaments with a resinous binding material prior to winding the filaments into a filament wound structure, comprising a housing, support

disposed centrally of said housing, an upper plate carried by said support and disposed transversely of said housing below the top thereof to provide an upper resin reservoir at the top of said housing above said plate, a lower plate carried by said support and disposed below said upper plate and above the bottom of said housing to provide a vacuum chamber between said upper and lower plates and a lower resin reservoir within said housing below said lower plate, resin seal means for forming a seal between the edge of each of said plates and said housing for sealing against resin and through which seals filaments are adapted to pass, means for closing the bottom of said lower resin reservoir and for sealing the same against resin while providing for passage of filaments, means for drawing a vacuum on said vacuum chamber, and means for supplying resin to said reservoirs.

2. A filament impregnating device in accordance with claim 1 in which said means for supplying resin to said reservoirs comprises a resin supply having a normal resin level at the elevation of the desired resin level in said upper resin reservoir, means for conducting resin from said supply to said lower reservoir, and means for conducting resin from said lower reservoir to said upper reservoir whereby said lower reservoir is completely filled with resin and the resin in said upper reservoir tends to rise to the level of the resin in said supply.

3. A filament impregnating device in accordance with claim 1 in which said resin seal means comprises an inflatable tube at the periphery of each of said plates adapted to cooperate with a sealing surface on said housing.

4. A filament impregnating device in accordance with claim 3 in which said support is provided with an air passage endwise thereof, and there is provided means for supplying air under pressure to said air passage, and means including bores in said upper and lower plates for connecting said air passage to said tubes for inflating the same.

5. A filament impregnating device in accordance with claim 4 in which said support comprises a pair of concentric tubes and said air passage comprises an annular space between said concentric tubes.

6. A filament impregnating device in accordance with claim 1 in which said means for closing the bottom of said lower resin reservoir comprises a pair of cooperating flap members including a first flap member carried by said housing and a second flap member carried by a rod extending lengthwise of said support and adjustable endwise therein, said flap members converging to provide a resin-tight seal between the same and being deformable to provide for movement of filaments between said flap members while maintaining the seal about the filaments.

7. A filament impregnating device in accordance with claim 6 in which said first flap member is annular and extends outwardly relative to said housing, and said second flap member is disc-like and engages said first flap member at the periphery thereof.

8. A filament impregnating device in accordance with claim 7 in which said support comprises a pair of concentric tubes, said rod extending lengthwise of the inner one of said concentric tubes, said resin seal means comprises an inflatable tube at the periphery of each of said plates adapted to cooperate with a sealing surface on said housing, means for supplying air under pressure to an annular air passage between said concentric tubes, and means including bores in said upper and lower plates for connecting said air passage to said inflatable tubes for inflating the same.

9. A filament impregnating device in accordance with claim 1 in which the means for drawing a vacuum on said vacuum chamber comprises an outlet from said vacuum chamber substantially at said lower plate, a vacuum cup, conduit means connected at one end to said outlet and having its other end opening into said vacuum

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cup to provide for drawing a vacuum on said vacuum chamber through said conduit and for drainage of resin from the bottom of said vacuum chamber into said vacuum cup, and means for drawing a vacuum on said vacuum cup at an elevation above the level of the accumulation of drained resin in said vacuum cup.

10. An impregnator for use in a winding machine for making low-void filament wound articles, said impregnator comprising a resin chamber adapted to contain resin, an exit from said chamber below the level of the resin, sealing means for sealing said exit against resin and providing for passage of roving therethrough while maintaining the seal, and means for guiding a roving through said resin chamber to said exit, said sealing means comprising an outer flap member that is substantially disc-like in shape and an inner flap member having a hub mounted in surrounding relation relative to said exit and a flange extending sharply outwardly and radially of said hub, means for supporting said outer flap member substantially normal to the axis of said hub and in converging relation relative to said flange with the periphery thereof in cooperation with the periphery of the flange so as to form therewith a generally extended and substantially acute angle whereby to inhibit thereat turbulence of said resin, means for guiding a roving

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passing through said exit into a path outwardly between said flap members and generally parallel to said flange, one of said flap members being formed of a soft flexible material capable of deforming about the roving passing between said flap members to seal tightly against the roving and the opposed flap member, and means for supporting said one of said flap members against the head of the resin in said resin chamber.

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MARS KAPLAN, Primary Examiner

U.S. Cl. X.R.

28—59; 118—405, 428, 429

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,473,511

October 21, 1969

Bruce E. Metz et al.

It is certified that error appears in the above identified patent and that said Letters Patent are hereby corrected as shown below:

In the heading to the printed specification, lines 4 to 7, "411 S. Cass Ave., Westmont, Ill. 60559; James T. Paul, Jr., 19 Harvard Road, Cooper Farms, Wilmington, Del. 19808; and James A. Le Noir, 246 Bassett Ave., Leedom Estates, New Castle, Del. 19720" should read -- Westmont, Ill., James T. Paul, Jr., Wilmington, Del., and James A. Le Noir, New Castle, Del., assignors to Hercules Incorporated, Wilmington, Del., a corporation of Delaware --.

Signed and sealed this 21st day of April 1970.

(SEAL)

Attest:

Edward M. Fletcher, Jr.

Attesting Officer

WILLIAM E. SCHUYLER, JR.

Commissioner of Patents