

[54] **SEALED WIRE ROPE AND STRAND AND METHOD OF MAKING**

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### Related U.S. Application Data

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1971, Pat. No. 3,681,911.

[52] **U.S. Cl.** ..... 57/149, 57/162

[51] **Int. Cl.** ..... D07b 1/16, D02g 3/36

[58] **Field of Search** ..... 57/35, 139, 144, 149, 153,  
57/156, 160, 162, 164

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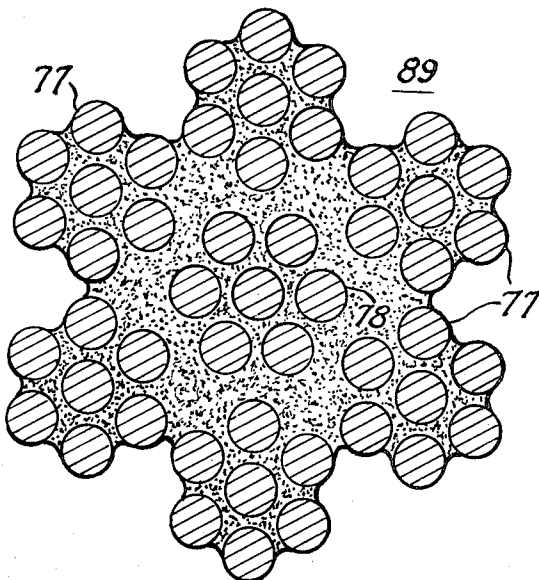
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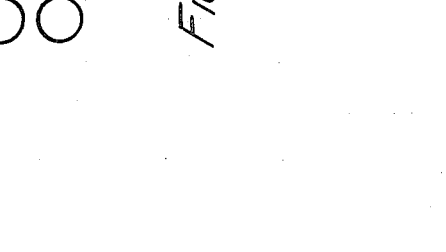
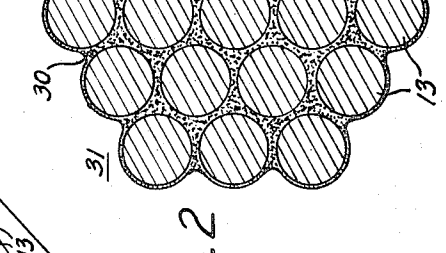
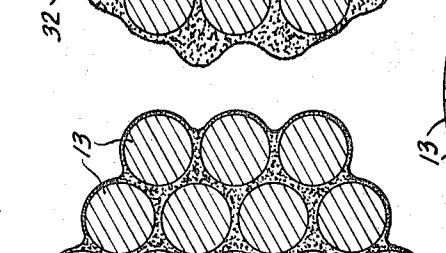
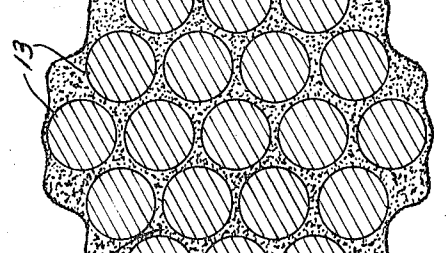
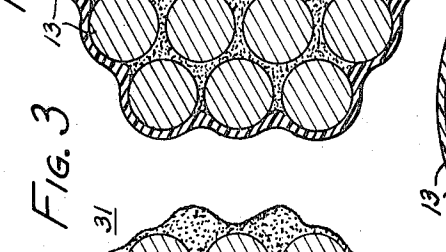
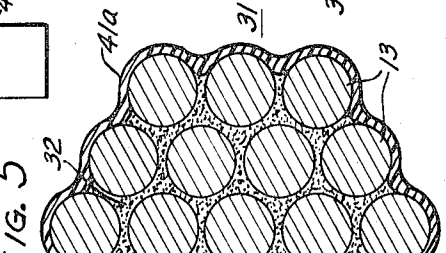
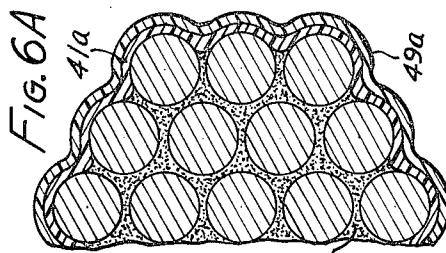
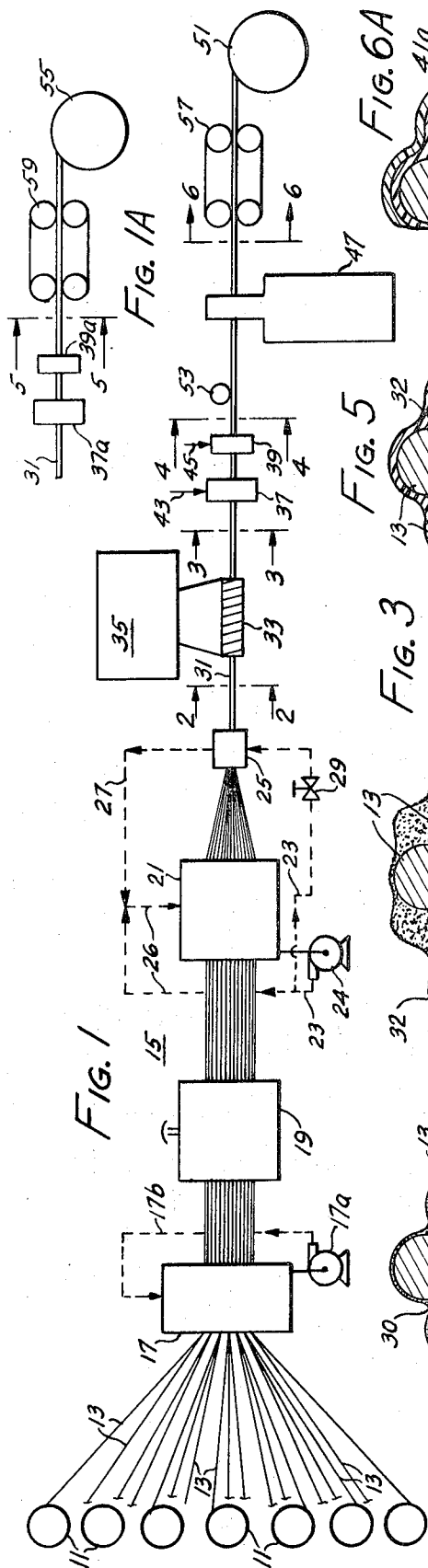
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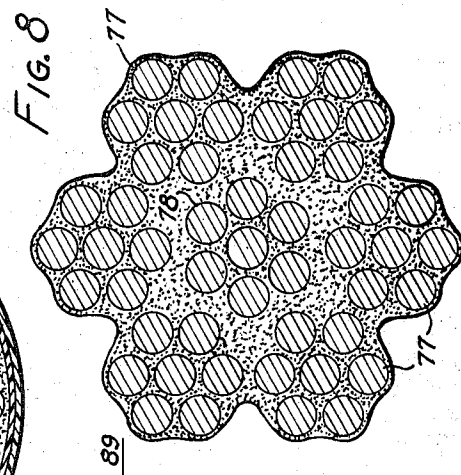
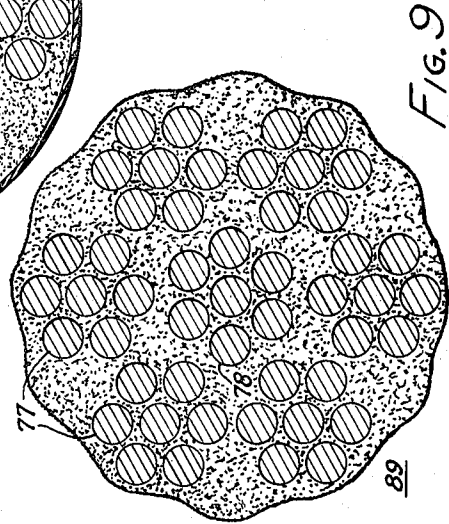
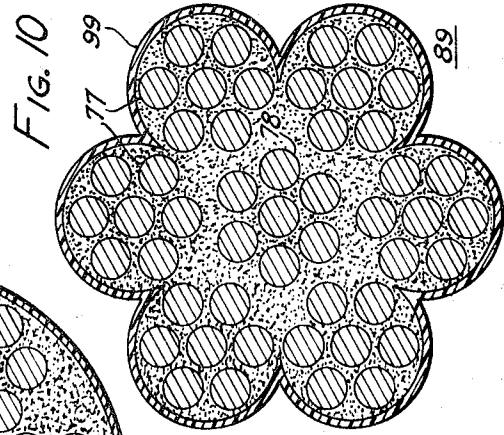
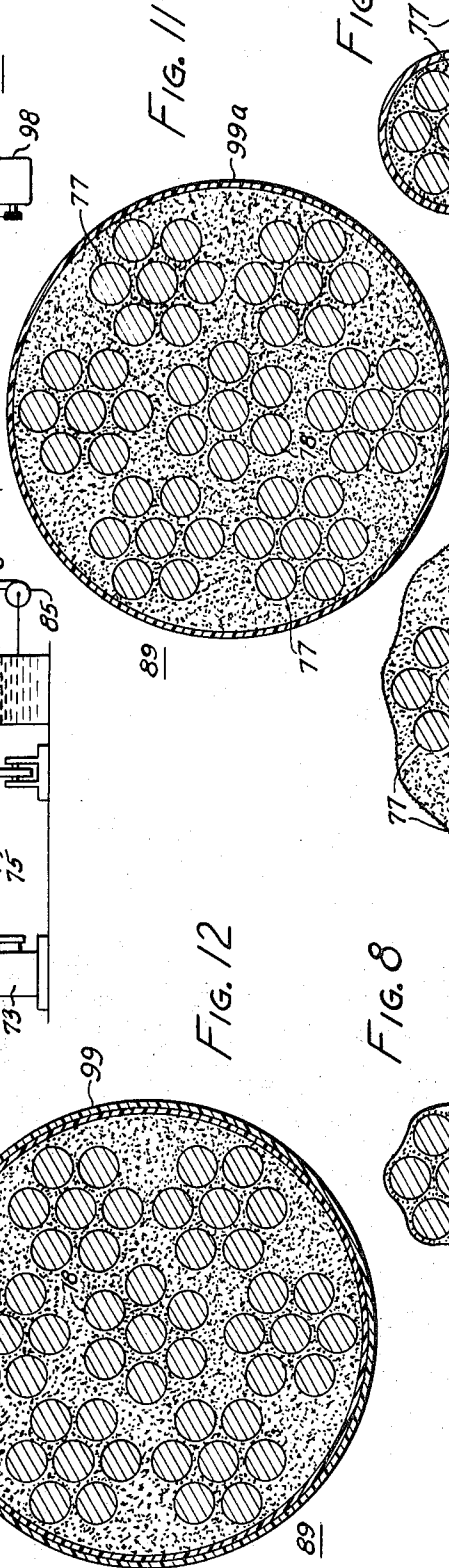
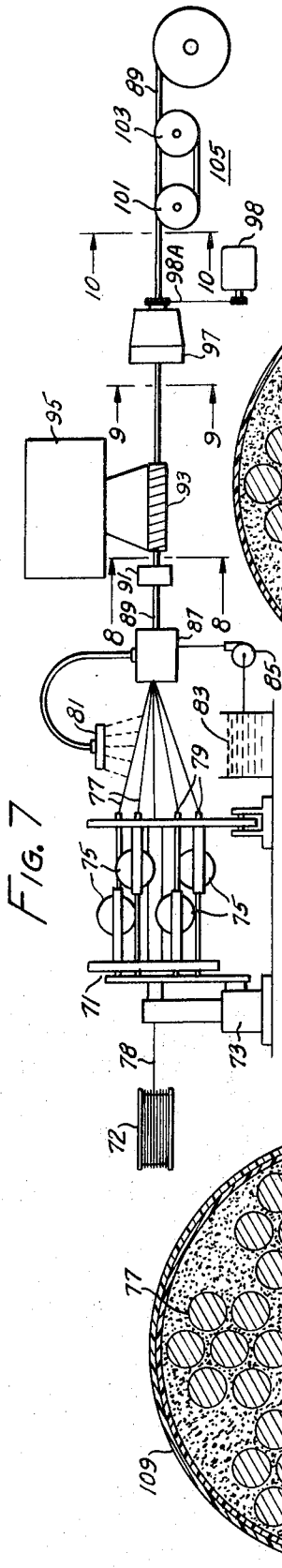
### [57] ABSTRACT

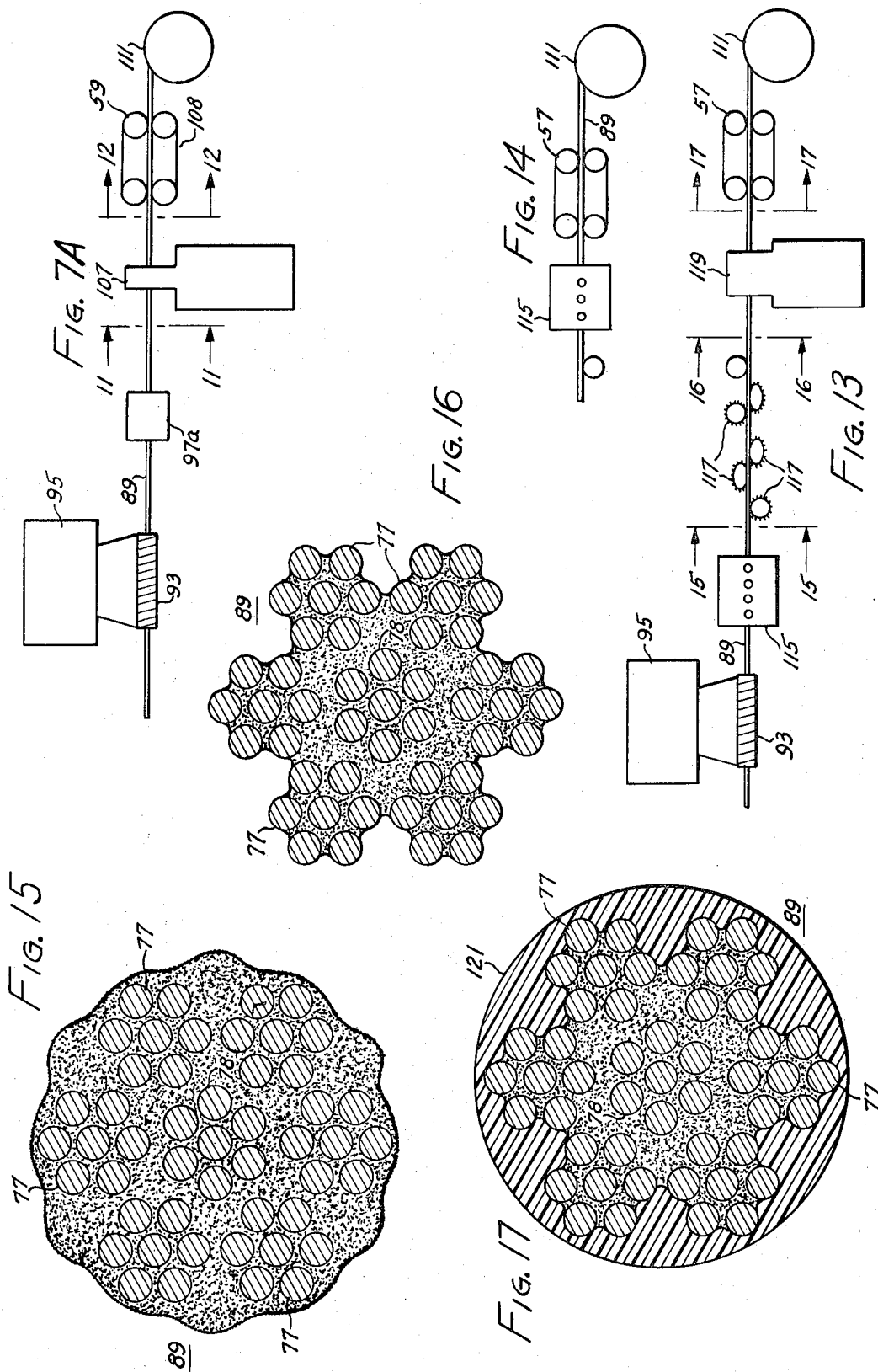
A wire rope or strand is impregnated with a plastic foam type internal sealant to cushion the wires and strands and provide corrosion protection by (a) initially impregnating the strand with a foamable plastic composition, (b) heating the strand under "free-blowing" conditions to foam the plastic composition uniformly about the wires or strands, and (c) preferably finally collapsing the foam material upon the surface of the strand by means of a cold die to form a dense outer plastic jacket. The foamable plastic composition before foaming serves as a lubricant within the stranding die so that no additional stranding lubricant is required. The resulting plastic impregnated wire rope or strand has uniform low interwire foam filler densities. Alternative constructions of impregnated rope or strand can be made.

**27 Claims, 32 Drawing Figures**









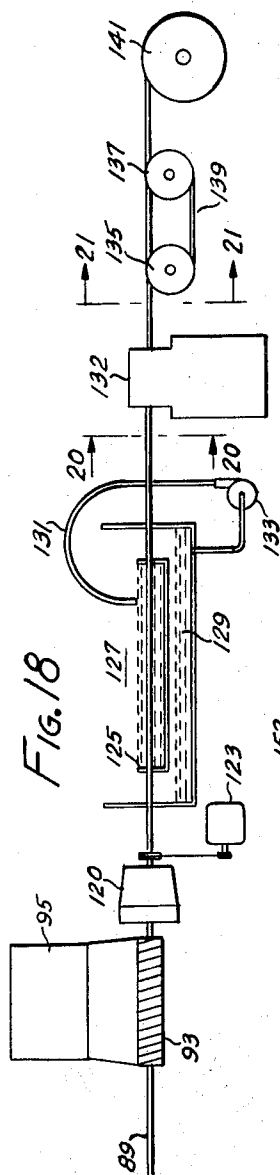


FIG. 18

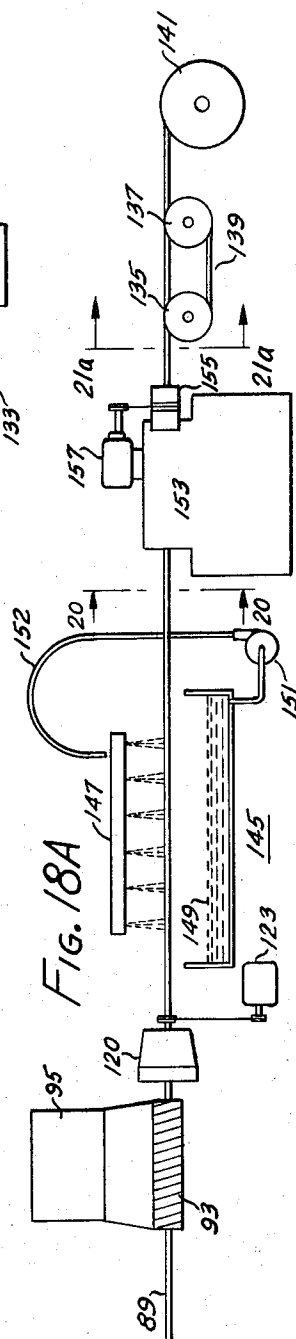


FIG. 18A

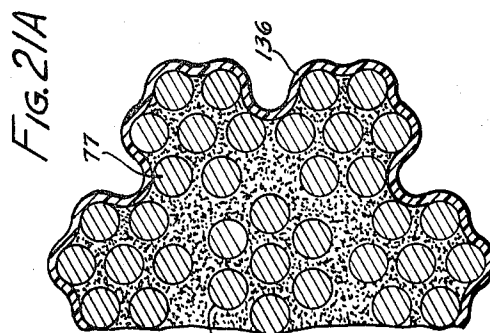


FIG. 21A

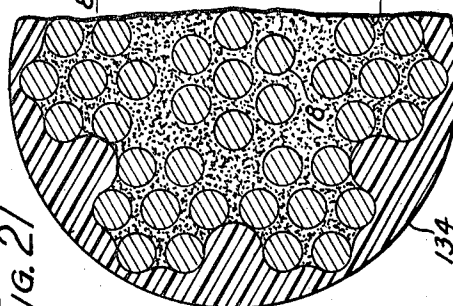


Fig. 21

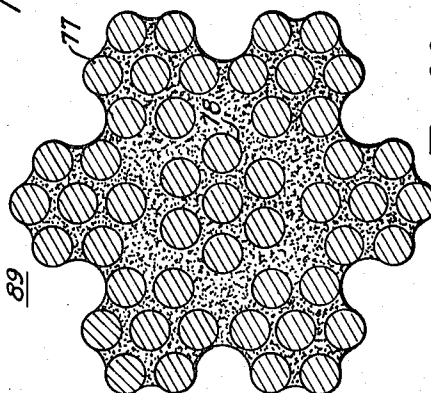


FIG. 20

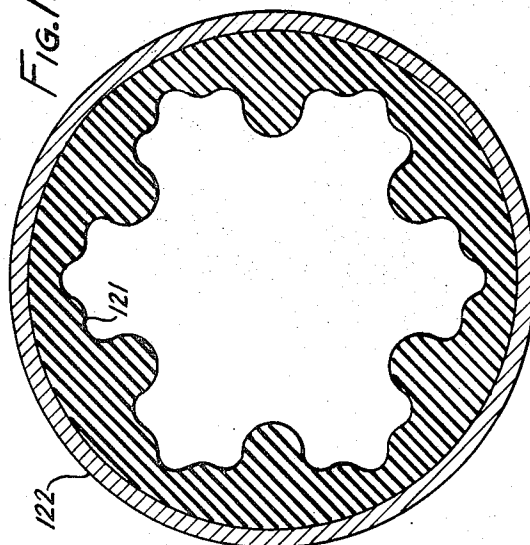
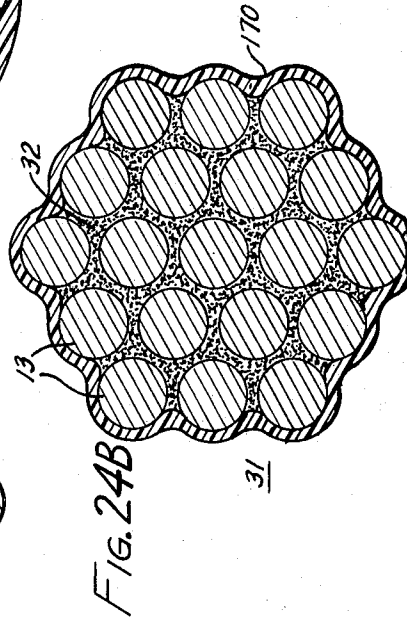
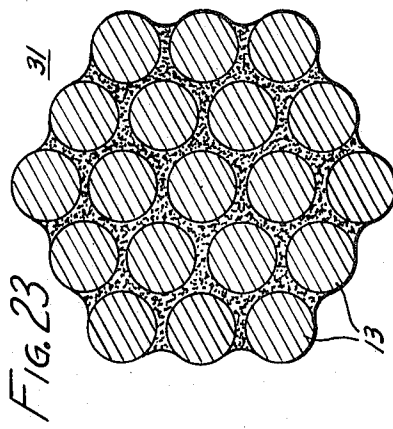
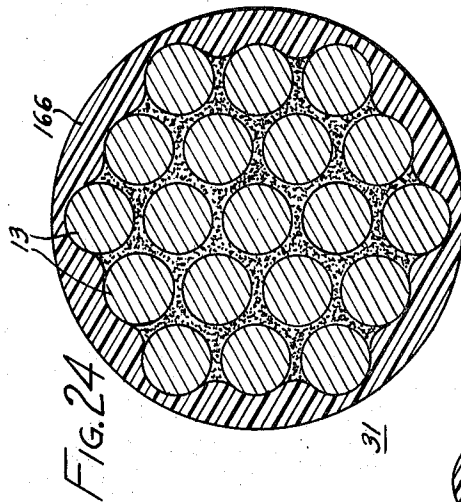
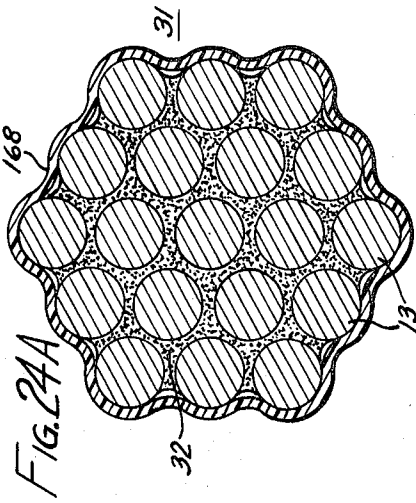
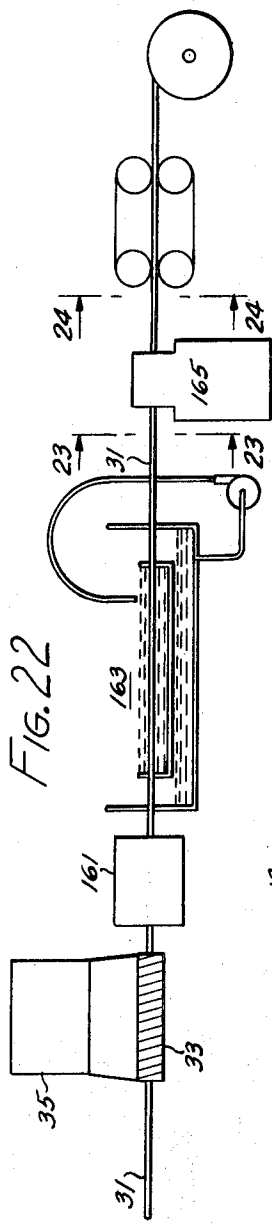


Fig. 19



# SEALED WIRE ROPE AND STRAND AND METHOD OF MAKING

## CROSS-REFERENCE TO RELATED APPLICATIONS

This application relates to an improvement in the method of making plastic foam impregnated wire rope and strand disclosed in the continuation-in-part application Ser. No. 112,211 filed Mar. 30, 1971, by Darral V. Humphries, now U.S. Pat. No. 3,681,911.

## BACKGROUND OF THE INVENTION

This invention relates to a method of sealing wire rope and strand for protection against corrosive environments. Wire ropes and strands can be generically referred to as "wire cable" and this definition is adopted in the description and claims hereinafter where convenient. Steel wires and strands are subject to internal corrosion of the component wires due to the entrapment of water within the structure of the strand between the individual wires.

Various expedients have been used to bar the entrance or the effects of entrance of water or other corrosive liquids and/or gases into wire strand and ropes including the provision of heavy lubricants, external plastic coatings and the encapsulation of the individual wires, wire strands or even the entire wire rope in solid plastic sheaths. Lubricants are soon lost from an otherwise unprotected rope or strand. External coatings and sheaths are subject to wear and upon rupture of the sheath at any point will admit moisture or other corrosive agents into the entire strand or rope. Solid encapsulation of the rope or strand, on the other hand, not only makes the structure too stiff and inflexible for many uses but is also difficult to effectively attain. Encapsulation of individual wires prior to fabrication also results in considerable stiffening of the rope subsequently fabricated from the wires, and the wire density, or close packing of the wires in the rope, is undesirably reduced by the additional thicknesses of the encapsulating plastic layers between the wires.

The foregoing difficulties have been obviated by the improved plastic foam impregnated wire rope and strand disclosed in the above referred to prior application of Darral V. Humphries. The method disclosed by Humphries for the fabrication of his wire rope and strand, however, while quite practical for use in the fabrication of many wire ropes and strands has proved to have several drawbacks. One of these drawbacks is the fact that the wires previously coated with a foamable plastic composition as shown in the Humphries application must be further lubricated before stranding of the wires. This lubrication has been found to sometimes interfere with the proper impregnation of the strand with the plastic foam. On the other hand if no lubrication is used proper stranding of the wires or strands composing the completed strand or wire rope, as the case may be, often does not proceed smoothly due to friction and rubbing between the component wires and between the wires and the inside surfaces of the stranding die. Secondly, it has been found that the foaming of the plastic within a confined water cooled member does not provide an outer dense and wear resistant plastic coating as desirable, particularly as to strength and durability, as might be required for some applications and the uniformity of the plastic foam impregna-

tion within the strand or rope is often poor. Poor uniformity may result in uneven properties such as flexibility and the like of the strands and ropes.

## SUMMARY OF THE INVENTION

The foregoing drawbacks of the prior method of fabricating a foam impregnated strand or cable have been obviated by the invention set forth in the present application.

In accordance with the present invention the uncured foamable plastic composition is applied to wires or strands approaching the stranding die either just prior to entrance of the wires or strands into the stranding die or after the wires or strand physically enter the stranding die so that the liquid foamable composition acts as an excellent lubricant for the stranding operation. As the completed strand or rope (hereafter referred to broadly as wire strand) exits from the stranding die all excess foamable composition is wiped from the surface of the fabricated wire strand by the sides of the die. The wire strand impregnated with the unfoamed foamable plastic composition is then transported to a heating means where the strand is heated to induce the foamable composition to foam. Foaming is done in the open or in a completely unconfined space so that the foam can expand from within the strand freely onto the surface of the strand. This unrestricted or "free-blowing" condition results in a much more uniform internal foaming than has previously been obtainable. The wire strand is then preferably transported while the foamable composition is still not completely hardened to a second die which acts to collapse the surface layers of foamed plastic into a dense hard protective jacket for the coated strand having the same composition as the underlying foamed plastic composition. In some instances the outer plastic foam layer which is usually collapsed into the protective jacket may be immediately stripped from the surface of the rope or strand by a die of appropriate clearance leaving a rope or strand completely impregnated internally with a uniform plastic foam but having a conventional outer steel surface. As an alternative the bare outer surface of the strand may be encapsulated in an outer dense hard plastic jacket.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 schematically shows a fabrication line for a parallel wire strand incorporating a plastic foam sealing treatment.

FIG. 1A is a schematic representation of a portion of an alternative fabrication line arrangement.

FIG. 2 is a cross-section of the strand fabricated in the apparatus of FIG. 1 at 2—2 in FIG. 1.

FIG. 3 is a cross-section of the strand of FIG. 1 at 3—3 in FIG. 1.

FIG. 4 is a partial cross-section of the completed strand at 4—4 in FIG. 1.

FIG. 5 is a cross-section of the completed strand with an alternative closely confining indented outer jacket formed in the alternative apparatus shown in FIG. 1A.

FIG. 6 is a partial cross-section of the completed strand of FIG. 4 with an optionable outer jacket of another plastic over the first plastic jacket as shown at 6—6 in FIG. 1.

FIG. 6A is a cross-section of the alternative completed strand of FIG. 5 with an additional optionable

outer jacket of another plastic over the first plastic jacket.

FIG. 6B is a cross-section of still another alternative embodiment of the completed strand of FIG. 5 with an additional optional jacket of another plastic over the first plastic jacket. A round outer surface is provided upon the outer surface of the outer jacket in FIG. 6B.

FIG. 7 is a schematic elevation of a fabrication line for a foamed plastic impregnated helical wire rope.

FIG. 7A is a schematic representation of a portion of an alternative fabrication line arrangement for a foamed plastic impregnated helical wire rope.

FIG. 8 is a cross-section of the wire rope being made in the apparatus of FIG. 7 at 8—8 in FIG. 7.

FIG. 9 is a cross-section of the wire rope at section 9—9 of FIG. 7.

FIG. 10 is a cross-section of the completed rope at 10—10 in FIG. 7.

FIG. 11 is a cross-section of an alternative form of the foamed impregnated wire rope with a smooth outer jacket formed in the alternative apparatus shown in FIG. 7A at 11—11.

FIG. 12 is a cross-section of the completed wire rope made in the alternative apparatus of FIG. 7A with an optionable outer jacket of another plastic over the first plastic jacket at 12—12 in FIG. 7A.

FIG. 13 is a schematic elevation of a portion of another alternative wire rope fabrication line, the first portion of which is similar to the line shown in FIG. 7.

FIG. 14 is a schematic elevation of still another alternative wire rope fabrication line the initial portion of which is similar to the line shown in FIG. 7.

FIG. 15 is a cross-section of the wire rope fabricated in the apparatus of FIG. 13 at 15—15 in FIG. 13.

FIG. 16 is a cross-section of the wire rope of FIG. 15 at 16—16 in FIG. 13.

FIG. 17 is a cross-section of the wire rope of FIG. 15 at 17—17 in FIG. 13.

FIG. 18 is a schematic elevation of a portion of an alternative wire rope fabrication line, the first portion of which is similar to the line shown in FIG. 7.

FIG. 8 is a schematic elevation of a portion of an alternative wire rope fabrication line the first portion of which is similar to the line shown in FIG. 7.

FIG. 19 is a cross-section through the wiping die 120 in FIG. 18.

FIG. 20 is a cross-section of the wire rope fabricated in the apparatus of FIG. 18 and FIG. 18A at 20—20 in FIGS. 18 and 18A.

FIG. 21 is a partial cross-section of the wire rope fabricated in the apparatus of FIG. 18 at 21—21 in FIG. 18.

FIG. 21A is a partial cross-section of the wire rope fabricated in the apparatus of FIG. 18A.

FIG. 22 is a schematic elevation of a portion of an alternative wire strand fabrication line, the first portion of which is similar to the line shown in FIG. 1.

FIG. 23 is a cross-section of the wire strand fabricated in the apparatus of FIG. 22 at 23—23 in FIG. 22.

FIG. 24 is a cross-section of the wire strand fabricated in the apparatus of FIG. 22 at 24—24 with an additional optional outer jacket of extruded plastic over the surface of the strand.

FIG. 24A is a cross-section of the strand coated in the apparatus shown in FIG. 22 with a fairly thin plastic coating applied by means of a tube type extruding apparatus.

FIG. 24B is a cross-section of the strand coated in the apparatus shown in FIG. 22 with a medium thickness plastic outer jacket formed in a pressure type extrusion apparatus.

#### DESCRIPTION OF THE PREFERRED EMBODIMENTS

In FIG. 1 there is shown a parallel wire strand fabrication line adapted for the production of foamed plastic impregnated parallel wire strand according to the present invention. A series of reels 11 having wires 13 coiled thereupon are arranged to feed the wires 13 into the fabrication line 15 where the wires pass initially through a primer applicator apparatus 17 which acts to apply a primer, if necessary, to the surface of the wires 13. (For convenience in illustration only a representative sample of reels 11 are shown). A pump 17a serves to recirculate the primer through the applicator 17 by means of piping 17b. The primer is applied if necessary to increase the adhesion between the wires 13 and the final foamed plastic impregnating composition. For example a phenolic-acrylic primer may be used with a foamed vinyl plastic impregnating composition. Specific primers may require baking or air drying to vent the solvent after application to the wires 13 and before the next process step.

From the primer applicator 17 the wires 13 pass through a solvent evaporation apparatus 19 to vaporize the primer solvent and then into a foamed plastic composition applicator apparatus 21. Foamed plastic applicator apparatus 21 is designed to apply a foamable plastic composition to the wires 13 as they pass through the applicator in any suitable manner such as by spraying the foamable plastic composition onto the wires, brushing the composition onto the wires or by simple immersion of the wires 13 into the foamable plastic composition. The foamed plastic applicator 21 is also connected by a suitable pipe 23 (shown by a dashed line) to a stranding die 25 through which the wires 13 are directed after they leave the applicator 21. A pump 24, which as shown may be a centrifugal pump, supplies foamable plastic material which drains from applicator 21 through pipe 23 to stranding die 25 and/or recirculates the foamable plastic material through recirculation pipe 26 back to applicator 21. The foamable plastic composition may therefore be applied principally to the wires alternatively either within the stranding die 25 or within the applicator apparatus 21, or both. The foamable plastic composition is, when pumped by pump 24 to stranding die 25, returned to applicator 21 through return pipe 27. If the foamable plastic composition is not to be applied to the wires 13 within stranding die 25 it may be cut off by closing valve 29. Likewise if the foamable plastic composition is to be applied to the individual wires 13 only within the stranding die 25 the operation of the particular applicator means within applicator 21 such as sprayers or brushes or conducting means (not shown) for conducting the wires through an immersing bath may be rendered inoperative so that the wires are coated with the foamable composition only within the stranding die 25.

As the individual wires 13 pass through stranding die 25 they are stranded into a parallel wire strand 31. During passage of the wires 13 through the stranding die 25 they are thoroughly lubricated to prevent binding and chafing upon each other or upon the sides of the stranding die by the interposition of the fluid and as yet unfoamed plastic material. The fluid plastic or polymer serves, prior to curing, as a very excellent wire lubricant. This lubricating action takes place whether the unfoamed plastic composition is applied to the wires 13 in applicator 21 or stranding die 25, or both. It will be recognized, however, that flooding the die 25 with the fluid plastic composition will provide the most thorough and complete lubrication during stranding, if such is necessary. If the plastic composition is applied to the wires solely within the applicator 21, it will be necessary for the applicator 21 to be spaced closely enough to the stranding die 25 to prevent any substantial amount of the fluid plastic composition from draining or evaporating from the wires 13 between the applicator 21 and the stranding die 25. Most, if not all, of the available plastics suitable for forming a flexible plastic foam also have good to excellent lubricity characteristics prior to hardening; for instance, polyurethane or vinyl polymers serve as very good lubricants.

As the wires 13 pass through the die 25 and exit therefrom through its narrowest dimensions the outer portions of the resulting strand are wiped almost clean of the foamable plastic material but the foamable plastic composition 30 is retained in the interstices between the wires as shown in FIG. 2. The preformed parallel wire strand 31 after exiting from the stranding die 25 then passes into and through the coils 33 of an induction-type furnace 35 where the wires 13 of the strand 31 are heated. The heating of the wires 13 transfers heat to the plastic composition 30 causing it to foam as shown in FIG. 3. The foaming of the foamable plastic composition completely fills the inner voids between the individual wires of the strand with foamed plastic 32 but does not decrease the density of the wires within the strand, or, in other words, does not increase the spacing between the individual wires within the parallel wire strand. Excess foamed material within the strand is forced from between the wires and onto the surface of the strand where it coats the surface of the strand as illustrated in FIG. 3. Since there is no restriction of any sort upon or about the surface of the strand to impede the exit of the foamed plastic material from the interior of the strand, so called "free-blowing" conditions obtain and a very evenly distributed foaming is attained within the strand resulting in more or less uniformly sized gas pockets throughout the plastic foam 32.

Before the foamed plastic composition has time to harden or cure into a solid foam layer upon the surface of the strand after the heating and foaming step, the parallel wire strand 31 is passed into a set of plastic foam collapsing dies 37 and 39 where the outer layer of foamed material is collapsed, due to passage through the cold die, into a dense wear resistant outer jacket 41 enveloping the foamed impregnated parallel wire strand 31. The dies 37 and 39 are preferably water cooled by water from lines 43 and 45 in order to keep the said dies relatively cold. In some cases it may be found advantageous to cool the dies with "heated" water so that they are maintained at a fairly constant, somewhat elevated temperature. The elevated temperature, which must be well below the solidification tem-

perature of the plastic if the plastic is a thermoplastic, prevents the plastic from sticking to the dies and thereby increases the uniformity and quality of the jacket. The dies 37 and 39 may be desirably formed from aluminum with a teflon coated inner surface to prevent the plastic from sticking to the walls of the die orifice.

The thickness of the outer plastic jacket 41 will be determined by the inside diameter of the collapsing dies 37 and 39 with respect to the outside dimensions of the metallic portions of the parallel wire strand 31. If the inside diameter of the dies, and particularly the leading die 35, is not much greater than the outside diameter of the strand a very dense layer of plastic, constituting an outer jacket 41, will be formed directly upon the surface of the strand. On the other hand, if the inside diameter of the dies is significantly larger than the outside dimensions of the metallic portions of the strand, the outer jacket 41 will be thinner and will have a significant layer of foamed plastic lying between it and the surface of the strand. By appropriate variation of the openings in the two collapsing dies 37 and 39 the ratio between the thickness of the outer jacket 41 and the underlying cushion of foamed plastic on the surface of the strand may be controlled.

If it is desired to fabricate a parallel wire strand without an outer dense plastic jacket 41 the collapsing dies 37 and 39 may be omitted. The surface of the strand will be in this case coated with a foamed plastic layer as shown in FIG. 3 having a density approximately the same as the density of the foamed plastic within the interior of the strand. Thus by foaming the plastic material without any outside constriction, or, in other words in a free-blowing condition, an extremely uniform plastic foam density will be obtained both within the interior and upon the exterior of the strand.

If a very closely confining outer jacket of dense plastic is desired upon the surface of the parallel wire strand 31 as shown in FIG. 5 the alternative apparatus shown schematically in FIG. 1A may be used. In this apparatus the foamed plastic collapsing dies 37a and 39a are constructed with an internal orifice having a peripheral configuration closely conforming to the outer shape and dimensions of the parallel wire strand 31. These dimensions of the collapsing dies will serve to collapse the unset or unhardened foamed plastic 32 at the surface of the strand into a dense outer jacket 41a conforming to the outer contours of the strand as shown in FIG. 5. It will be understood that although in each case two foamed plastic collapsing dies 37 and 39 or 37a and 39a are shown a greater or lesser number of collapsing dies may be used depending upon circumstances.

If it is desired to have an outer plastic jacket over the strand having a different composition from the composition of the plastic foam within the interior of the strand, suitable commercial type jacketing apparatus 47 may be provided to extrude an overall outer jacket upon the strand. The outer jacket, for instance, might be composed of nylon or other abrasion resistance plastic such as polyurethane, high molecular weight polyethylene, etc. This outer jacket may in some cases, if desired, be extruded directly over the foamed plastic impregnated strand without forming an intermediate outer jacket 41 of the same composition as the foamed plastic by means of the collapsing dies 37 and 39. It is, however, much preferable to extrude the outer jacket

49 over the initial jacket 41 formed by the dies 37 and 39 as shown in FIGS. 6, 6A or 6B. A much more uniform jacketing is attained by proceeding in this manner.

FIG. 6A shows a strand having an outer extruded jacket 49a which follows the contours of an underlying dense outer jacket 41a. FIG. 6B shows a strand having an outer pressure type extruded jacket 49b of plastic having a different composition from the dense underlying jacket 41a and which outer plastic fills in the contours of the jacket 41a to form a uniform outer surface on the strand.

After the strand 31 leaves the jacketing apparatus 47 and passes through the catapuller 57 it may be coiled upon reel 51 in any suitable manner such as by rotating the strand from side about its axis to relieve the stress in the individual wires caused by bending the parallel wire strand structure. If the outer extruded jacket 49, 49a or 49b, is not desired, the strand 31 may bypass the extrusion apparatus 47. In FIG. 1A after the strand passes through the catapuller 59 it is directed to reel 55 for reeling in the normal manner with alternate rotation about the axis of the strand. Any suitable catapuller device 57 or 59 may be provided to draw the parallel wire strand through the preceding apparatus and direct it to the reels 51 or 55 respectively.

FIG. 7 illustrates apparatus suitable for applying the method of plastic foam impregnation of the present invention to the fabrication of a plastic foam impregnated helical wire rope.

In FIG. 7 a flyer 71 rotatably by motor 73 supports a series of rotatable reels 75 each of which has coiled thereupon a helical wire strand 77. The wire strands 77, which may previously have been primed with a material such as a phenolic-acrylic type primer to promote adhesion between the wires of the strand and a later applied vinyl type plastic foam material, pass through guides 79 mounted in the flyer 71 to one end of the flyer where they pass through a spray apparatus 81 which sprays a copious amount of a vinyl type foamable plastic material onto the strands 77. Excess fluid plastic drops into collection pan 83 below the spray apparatus and is recirculated by the pump 85 through the spray apparatus 81. Pump 85 also circulates some of the fluid foamable plastic material to a stationary stranding die 87 through which the strands 77 pass. The strands 77 are stranded within die 87 around a central strand 78 derived from reel 72 into a helical wire rope 89 comprised of the various wire strands 77 and 78. As the wire strands 77 and 78 pass through the stranding die 87 chafing and friction between the strands and component wires and between the strands and the die is eliminated or drastically reduced by the lubricity of the foamable plastic material bathing the individual strands 77 as they pass through the stranding die 87.

As the strands 77 pass through stranding die 87 and are stranded together into a wire rope the outside of the resulting wire rope 89 is wiped clean except for any foamable plastic material which may be left in the interstices between the strands 77. If desired, the rope 89 may then be passed through an additional wiping means 91 where suitable brushes or the like wipe excess fluid plastic material from the surface of the wire rope including the interstices between the strands 77. A cross-section of the wire rope 89 after it passes through the wiper 91 is shown in FIG. 8.

The wire rope is next passed through an induction coil 93 of an induction furnace 95 where the individual wires and strands of the rope 89 are induction heated. The heat from the metal components of the rope 89 is transferred to the plastic material and induces foaming of the plastic due to the gas generated by the foaming agent contained in the plastic when it is exposed to the heat induced by the induction furnace 95. The rope 89 is completely unconfined during this foaming step so that some of the plastic foam material is forced from the interior of the strands onto the surface of the strands and the wire rope and the plastic material remaining within the strands and the interior of the wire rope develops a very evenly distributed density pattern which will not interfere in any manner whatsoever with the flexibility or wire density of the rope 89 after solidification of the plastic foam. A cross-section of the wire rope 89 after it passes through the coil 93 of the induction furnace 95 is shown in FIG. 9.

Before the plastic foam material has hardened or set after the free foaming step in the induction coil 93, the rope 89 is next passed into and through a rotatable water cooled collapsing die 97 having a spiral interior orifice matching the spiral configuration of the strands 77 in the helical wire rope 89. As in the apparatus shown in FIG. 1 the collapsing die 97 may preferably be formed from aluminum or aluminum alloy with a Teflon (polytetrafluorethylene) coating on the interior surfaces of the die orifice to prevent the plastic from adhering to the metallic die. Warm water may also be circulated through the die to "cool" the die and at the same time further aid in preventing adherence of the plastic thereto or possible differential solidification or curing of the plastic therein. Various different but well known measures for preventing adherence of the plastic can be taken for different plastic materials.

As the wire rope 89 passes through die 97 the die is rotated by the motor 98 through a belt 98A to allow the rope to pass freely. The rotating die 97 collapses the still unhardened or unset plastic foam into a dense wear resistant outer plastic coating or jacket 99 over the entire wire rope 89 including the plastic foam within the component strands 77 and the interior of the rope. A cross section of the wire rope 89 after the formation of the jacket 99 in the rotating die 97 is shown in FIG. 10.

After passage through the rotating die 97 the plastic foam impregnated wire rope 89 passes around the two grooved sheaves 101 and 103 of a double capstan 105 which serves to pull the strands 77 and rope 89 through the preceding apparatus.

FIG. 7A shows a schematic elevation of an alternative arrangement of a coating line for treating the wire rope 89 in which the rope after passing through the induction coil 93 passes through a non-rotating collapsing die 97a having a generally round internal orifice which collapses or compacts the plastic foam initially on the surface of the wire rope as seen in FIG. 9 into a circular outer jacket 99a as seen in the cross section of the wire rope shown in FIG. 11.

If desired an additional commercial extrusion apparatus 107 may be positioned either before (as shown in FIG. 7A) or subsequent to the catapuller type capstan 108 which may function to extrude a separate plastic jacket 109 of some suitable plastic such as nylon or the like over the underlying jacket 99 of collapsed foamed vinyl plastic upon the surface of the wire rope 89 as

shown in FIG. 12. Alternatively the outer plastic jacket 99 may be extruded over a contoured outer plastic jacket as shown in FIG. 10 resulting in a final jacketed wire rope similar either to the jacketed strand shown in FIG. 6A or the jacketed strand shown in FIG. 6B.

After passing through the extruding apparatus 107 the jacketed and impregnated wire rope may be coiled upon a reel 111 for shipment or further processing.

In FIG. 13 there is shown a portion of a further alternative apparatus arrangement for coating wire rope 89 as shown in FIG. 7. In FIG. 13 the wire rope 89, after passing through the induction coil 93, where the plastic foam is expanded by heat under free blowing conditions, is passed through a cooling chamber 115 where the foamed plastic is quickly cooled and hardened by any suitable cooling agent such as forced cooled air blasts, fine sprays or mists of a cooling liquid such as water or other like cooling agents which will not harm the foamed plastic material. After emerging from the cooling chamber the wire rope will appear in cross section as seen in FIG. 15. The plastic foam material will be completely, but just barely, solidified or hardened. The wire rope 89 is, as soon as the foamed plastic material is completely solidified, passed between a series of wire brushes 117. The brushes 117 will preferably be rotating in a direction contra to the passage of the rope 89 between them. Each brush will be positioned so that it rides in one of the interstices between the individual outer strands 77 of the wire rope 89. As the rope 89 passes the brushes 117 each brush will strip away an outer section of plastic material from the surface of the strand. The newly solidified plastic foam parts very readily along any narrow constriction between two individual strands or two individual wires as seen in cross-section in FIG. 16, leaving a completely bare surface upon the wire rope which is very easily inspectable for defects where such inspection is important, for instance, in ski lift ropes and the like. The interior of each individual strand 77 and the interior of the rope 89 as a whole remains thoroughly impregnated or filled with an adherent, uniform plastic foam which is effective to prevent the entrance of moisture and other corrosive substances into the interior of the rope and also serves to somewhat cushion the strands upon each other. While the outer plastic foam layer initially parts cleanly from the surface of the wire rope as a whole with only a little external stripping force, and from the outer surface of each individual strand with the exertion of only a fairly minor external stripping force, it will be found that if the solidified plastic is allowed to age for a substantial period of, for example, several hours, it will occasionally no longer tend to strip cleanly from the outer surface of the rope.

It is sometimes advantageous after the foam is stripped from the surface of the wire rope to pass the stripped rope through a suitable commercial type extruder 119 to extrude a plastic jacket 121 of the same or a different plastic over the outside of the rope as seen in cross-section in FIG. 17. FIG. 17 shows a rather heavy pressure extrusion type outer coating. The supplemental outer jacket 121 may be formed for example from nylon, polypropylene or similar tough plastics to form a wire rope having a tough thick plastic jacket over the outside and a uniform flexible internal sealing impregnation of plastic foam internally so that the wire rope is completely sealed against internal or external corrosive agents. The resulting wire rope needs no in-

ternal lubrication to maintain flexibility or to retard corrosion.

If desired the apparatus in the coating line shown in FIG. 13 may be modified as seen in FIG. 14 so that the foamed plastic coating is merely cooled in a cooling chamber 115 and then reeled on the reel 111. The finished impregnated wire rope will in this case have a foamed plastic coating and impregnation as seen in cross section in FIG. 15 with a very uniform foam impregnation throughout.

As an alternative to the apparatus shown in FIG. 13, the apparatus shown in FIGS. 18 or 18A may be used to produce either a wire rope with a bare surface as shown in FIG. 20 to facilitate inspection of the outer wires and strands of the wire rope, or a wire rope with an extruded outer jacket as shown in FIGS. 21 or 21A.

In FIG. 18, the wire rope after passing through the induction coil 93 is directed through a rotating die 120 which rotates at the same rate as the apparent rotational rate of the lays of the rope at the location of the die 120 as the rope passes through the die. Die 120 is preferably rotated by motor 123 but could, if necessary, be rotated by the passage of the helical wire rope through the die. The die 120 is preferably formed from a medium hardness rubber or like material which has a die orifice as seen in FIG. 19 of the same general outline as the outer contour of the wire rope 89 but slightly smaller than the diameter of the wire rope so that the outside of the rope is thoroughly wiped by the inner surfaces of the die as the rope passes therethrough. A cross-section of the rotatable rubber die is shown in FIG. 19. In FIG. 19 the rubber portion 121 of the die is surrounded by an outer metal reinforcing cylinder 122. The die 120 is best positioned very near and preferably within a few inches of the induction foaming coil 93 so that the surface of the rope is wiped clean of foamed plastic material before the plastic has a chance to begin to solidify or cure. After the wiped wire rope passes from the rotating die 120, it passes immediately through a quench trough 125 of a weir type quench apparatus 127 where the outer bare wires of the strands of the rope are quenched. The quenched metal wires of the strand immediately quench the adjacent foamed plastic material so that it cannot extrude, under the pressure of any remaining gas pressure in the foamed plastic, outwardly between the wires and strands onto the surface of the wire rope. While the plastic foam and wires within the interior of the wire rope are not immediately cooled below the point at which the plastic is mobile, the immediate freezing or solidification of the plastic adjacent to the outer wires is sufficient to prevent any extrusion or migration of the interior foamed material onto the surface of the rope 89 or the component strands of the rope. Overflow from the quench trough 125 is caught in reservoir 129 and is returned to the quench trough 125 through the pipes 131 and pump 133.

After the wire rope passes from the quench trough 125 it has an adherent internal foam impregnation and a bare surface as seen in FIG. 20. The bare impregnated wire rope 89 then passes to a commercial type extrusion apparatus 132 where an outer jacket 134 composed of a dense unfoamed plastic having either the same composition as the plastic of internal foam impregnation or alternatively a different composition such as nylon, polypropylene or the like is extruded

over the outside of the rope as seen in FIG. 21. The outer dense plastic jacket 134 as seen in FIG. 21 serves as a very effective protection for the outside of the wire rope 89.

As an alternative the wire rope 89 after foaming and quenching can be passed through the extruder 132 without activating the extruder so that the final product is a foam impregnated wire rope having a completely bare surface as seen in cross section in FIG. 20.

The bare surfaced wire rope, as shown in FIG. 20, or the jacketed wire rope, as shown in FIG. 21, is finally passed about the drums 135 and 137 of a double drum capstan 139, and is then reeled upon the reel 141 for storage or use.

In FIG. 18A there is shown an alternative method of forming the foam impregnated wire rope shown in FIG. 20 or an alternative type of extruded jacket shown in FIG. 21A. In FIG. 18A after the wire rope passes through the rotating rubber wiping die 120 it passes through a spray quench type quenching apparatus 145 to quickly quench the outer wires of the rope and solidify or set the adjacent portions of the plastic foam. The quench apparatus 145 is comprised of a quenching head 147 and a catch reservoir 149 which collects the spray water. A pump 151 returns the spray water to the spray head 147 through a pipe 152.

After the foam impregnated rope passes through the spray quench it passes to a commercial extruding apparatus 153 which extrudes an outer plastic jacket of the same composition or another composition than the composition of the plastic foam over the exterior of the wire rope. The final extrusion die 155 of the extruder 153 in this case will have a contoured shape designed to fit fairly closely about the surface of the wire rope. The die 155 is rotatably mounted upon the body of the extruder and is arranged to be driven by a motor 157 mounted upon the extruder 153. As the wire rope 89 passes through the contoured orifice of the die 155 it is jacketed with a closely fitting jacket of a strong dense plastic such as nylon or polypropylene or even of the same composition of plastic from which the plastic foam is composed. The wire rope after it passes from the extruder 153 will have a cross section such as shown in FIG. 21A. The jacket 136 in this case conforms to the outer contours of the rope 89. As an alternative to the use of rotating die 155 type pressure extruder shown in FIG. 18A, a conventional vacuum type extruder could be used in which an oversize outer tube is extruded concentrically about the wire rope and then drawn down tightly upon the surface of wire rope by the application of a vacuum within the extruded tubing plus, usually, a slower extrusion rate than the rate of travel of the wire rope through the extruder. The differential rate between the extrusion of the concentric tube of plastic and the speed of travel of the wire rope serves to aid in drawing the still soft plastic of the tube tightly down against the surface of the wire rope. In some instances either the vacuum or the differential speed may serve along to draw the plastic tube down tightly against the rope surface. Where a vacuum is used, special vacuum orifices must be provided in the end of the extruder head since the plastic foam impregnation within the wire rope prevents a vacuum from being "pulled" or established through the interior of the wire rope or strand.

FIG. 22 is a schematic elevation of an alternative wire strand fabrication line similar to the line shown in

FIG. 1. Only a portion of the line is shown in FIG. 22 and it will be understood that the initial portion of the line will be essentially similar to the initial portions of the line shown in FIG. 1. In FIG. 22 an induction coil 33 serves to heat the wires of the strand and foam the surrounding plastic. Immediately subsequent to the induction coil 33 there is positioned in the line a wiping die 161 which serves to wipe all the plastic foam which has been extruded onto the surface of the strand from the strand. The die 161 is preferably made from a medium hard rubber which will conform closely to the surface of the strand as it passes through the die. Immediately subsequent to the die 161 there is positioned a weir type quench arrangement 163 for quenching the wire strand. This quench arrangement is substantially identical to the quench 127 shown in FIG. 18 and serves to quench the outer wires of the strand 31 and the immediately adjacent plastic foam so that the plastic foam remaining within the interior of the strand cannot escape from the interior of the strand prior to complete solidification or curing of the plastic foam.

From the quench 163 the strand 31 passes to a commercial type extruder 165 which extrudes an external jacket of a strong plastic either having the same composition as the plastic of which the plastic foam is composed, or any other suitable plastic such as nylon or polypropylene, over the exterior of the strand to form a jacketed strand as shown in FIG. 24.

For some purposes it is very desirable to have a strand with an internal adherent foam impregnant to keep out external corrosive agents but having a bare surface so that the external condition of the strand can be easily inspected. Such a strand is particularly desirable on ski lifts, cable cars, bridge suspender cables and other applications where the strand must be frequently inspected. In such cases the strand 31 may be passed through the extruder 165 without operating the extruder, or else may be made to completely by-pass the extruder, so that the final product is a bare surfaced strand as shown in FIG. 23.

The extruded jacket may either be fairly thick and uniform externally as shown by the jacket 166 in FIG. 24 or may be thin and contoured to match the contour of the outer surface of the strand as shown by the jacket 168 in FIG. 24A, depending upon the type of extruder used. A pressure type extruder having a large extruding orifice will provide the outer extruded jacket shown in FIG. 24 while a vacuum type extruder will provide an external jacket such as shown in FIG. 24A. A pressure type extruder having a fairly close fitting contoured die orifice will, on the other hand, provide an external jacket 170 such as shown in FIG. 24B. This type of jacket is in some respects more desirable in that there is a more intimate contact between the plastic of the jacket 170 and the plastic foam impregnation in the interior of the strand. The same distinction can be made with respect to the jacketing of a wire rope as shown in FIG. 21A. In this instance, however, the use of a vacuum type extruder will usually result in an even less intimate contact between the plastic of the jacket and the plastic foam impregnation in the interior of the wire rope because of the additional more pronounced interstices between the strands of the rope in addition to the small interstices between the wires of the individual strands.

The plastic used in the present invention may be of any suitable composition such as vinyl plastic, or pref-

erably plastisol, having an organic nitrogen compound such as azodicarbonamide as a foaming agent. The foaming agent when heated above its decomposition temperature decomposes and expands the plastic into a foam. Azodicarbonamide, for example, will decompose into nitrogen and carbon dioxide which expand the foam. Another suitable composition would be a foamable polyurethane consisting of a thermosetting elastomer filled with expandable plastic beads. When exposed to heat the plastic of the beads softens and an entrapped gas therein expands the plastic into a foam. The polyurethane elastomer matrix provides cross linking. Any other plastic composition which is flexible, tough and adherent to metal, with or without the use of a suitable primer may be used with a foaming agent to coat the strand.

The individual wires and strands can be coated with a foaming composition in other ways than those shown. Likewise the primer for the wires and strands, if a primer is to be used, may also be applied in various other manners than those shown. Cooling of the plastic foam collapsing dies 37, 39 and 97 may likewise be accomplished in any suitable manner.

It will also be readily understood that a helical wire strand may be impregnated with a plastic foam in substantially the same manner as shown for a helical wire rope.

We claim:

1. A method of fabricating a plastic foam impregnated wire cable comprising:

- a. applying a foamable plastic composition to the individual linear components of a wire cable prior to fabrication of said linear components into said cable,
- b. forming said linear components into a wire cable in a suitable forming means,
- c. passing said wire cable to a heating means and applying heat to said foamable plastic composition in said heating means by the application of heat to the cable, and
- d. allowing the plastic composition to foam between and about the said wires of the cable under free-blowing conditions without external confinement.

2. A method of fabricating a cable according to claim 1 wherein the linear components are formed into a wire cable in a stranding die in which the foamable plastic composition serves as substantially the sole lubricant of the stranding operation.

3. A method of fabricating a cable according to claim 2 wherein the foamable plastic composition is applied to the linear components prior to their reaching the stranding die.

4. A method of fabricating a cable according to claim 2 wherein the foamable plastic composition is applied to the linear components substantially within the stranding die.

5. A method of fabricating a cable according to claim 2 additionally comprising:

- e. passing the cable subsequent to the free foaming step of (d) and before the plastic foam composition completely sets through a cold die means having an inside diameter greater than the outside diameter of the metallic portions of said cable but smaller than the overall dimensions of the foamed plastic portion of the cable whereby at least a portion of the foamed plastic composition upon the surface of

the cable is smoothed and compacted into an integral hard dense protective layer of plastic surrounding the foamed plastic impregnated cable.

6. A method of fabricating a cable according to claim 5 wherein an outer jacket of dense plastic is subsequently extruded over the hard, dense layer of plastic formed in step (e).

7. A method of fabricating a cable according to claim 6 wherein the outer jacket of dense plastic extruded over the layer of step (e) is composed of a plastic having a different chemical composition from the foamed plastic layers.

8. A method of fabricating a cable according to claim 1 additionally comprising:

- e. passing the cable subsequent to the free foaming step of (d) and before the plastic foam composition completely sets through a cold die means having an inside diameter greater than the outside diameter of the metallic portions of said cable but smaller than the overall dimensions of the foamed plastic upon the outer portions of the cable whereby at least a portion of the foamed plastic composition upon the surface of the cable is smoothed and compacted into an integral hard dense protective layer of plastic surrounding the foamed plastic impregnated cable.

9. A method of fabricating a cable according to claim 8 wherein an outer jacket of dense plastic is subsequently extruded over the hard, dense layer of plastic formed in step (e).

10. A method of fabricating a cable according to claim 9 wherein the outer jacket of dense plastic extruded over the layer of step (e) is composed of a plastic having a different chemical composition from the foamed plastic layers.

11. A method of fabricating a cable according to claim 1 additionally comprising:

- e. cooling the foamed plastic composition to harden said plastic foam, and
- f. stripping the outer layers of foam from the surface of the wire rope to leave a substantially bare wire rope surface.

12. A method of fabricating a cable according to claim 11 wherein the cable is a wire rope and the stripping of the outer plastic layers is accomplished while the plastic is in a condition such that the outer layers of plastic are removed along parting lines extending between adjacent wires and adjacent strands in said wire rope at substantially the point of closest clearance between the said adjacent wires and adjacent strands.

13. A method of fabrication of a cable according to claim 12 wherein the cable is passed between rotating brushes to effect the stripping of the outer layers of plastic foam from the surface of the wire rope.

14. A method of fabricating a cable according to claim 11 additionally comprising:

- g. applying a heavy outer plastic jacket about the bare outer surface of the strand in intimate contact with the outer metal surface of the rope.

15. A method of fabricating a cable according to claim 14 in which the outer plastic jacket is extruded upon the wire rope.

16. A method of fabricating a cable according to claim 1 additionally comprising:

- e. wiping substantially all foamed plastic from the surface of the cable immediately subsequent to

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foaming of said plastic composition in step (d) while said foam remains unhardened,

f. quenching said cable in a cooling fluid immediately subsequent to wiping the foamed plastic from the surface of said cable.

17. A wire rope sealed against internal migration of corrosive agents comprising:

a. a plurality of wire strands helically laid about each other to form a wire rope having an exposed exterior surface,

b. a plastic foam impregnating the interior of the said strands and the interior of the wire rope and intimately surrounding and contacting the interior surfaces of all component wires of said strands,

c. the internal plastic foam impregnation extending at least to the point of closest clearance between adjacent outer wires of said strands and between the wires of adjacent outer strands but not extending over the exterior surfaces of the outer strands and wire which are exposed to potential contact with adjacent objects.

18. A wire rope according to claim 17 additionally comprising:

d. an outer dense plastic jacket surrounding the outside of said wire rope and contacting the surfaces of the outer wires of said strands of said rope.

19. A wire rope according to claim 18 wherein the dense outer jacket is in intimate contact with the plastic foam internal impregnant.

20. A wire rope according to claim 18 wherein the outer dense plastic jacket is an extruded jacket having a different chemical composition from the plastic foam internal impregnant.

21. A wire rope according to claim 19 wherein the outer dense plastic jacket is an extruded jacket having a different chemical composition from the plastic foam internal impregnant.

22. A wire strand sealed against internal migration of

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corrosive agents comprising:

a. a plurality of wires forming a wire strand having an exposed exterior surface,

b. a plastic foam impregnating the interior of said strand and intimately surrounding and contacting the interior surfaces of all component wires of said strand,

c. the internal plastic foam impregnation extending at least to the point of closest clearance between adjacent outer wires of said strand but not extending over the exterior surfaces of the outer wires of the strand which are exposed to potential contact with adjacent objects.

23. A wire strand according to claim 19 additionally comprising:

d. an outer dense plastic jacket surrounding the outside of said wire strand and contacting the outer surfaces of the outer wires of said strands.

24. A wire strand according to claim 23 wherein the dense outer plastic jacket is in intimate contact with the plastic foam internal impregnant.

25. A wire strand according to claim 23 wherein the outer dense plastic jacket is an extruded jacket having a different chemical composition from the plastic foam internal impregnant.

26. A wire rope according to claim 17 wherein the internal plastic foam impregnation extends not substantially farther outward between the various strands and wires than the point of closest clearance between adjacent outer wires of said strands and between the wires of adjacent outer strands.

27. A wire strand according to claim 22 wherein the internal plastic foam impregnation extends not substantially farther outward between the outer wires of the strand than the point of closest clearance between the adjacent outer wires of said strands.

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