

- [54] **INTEGRALLY-WOUND ANTENNA
HELIX-COILFORM**
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- [51] Int. Cl. **H01q 1/36**
- [58] Field of Search **343/895, 873**

[56] **References Cited**

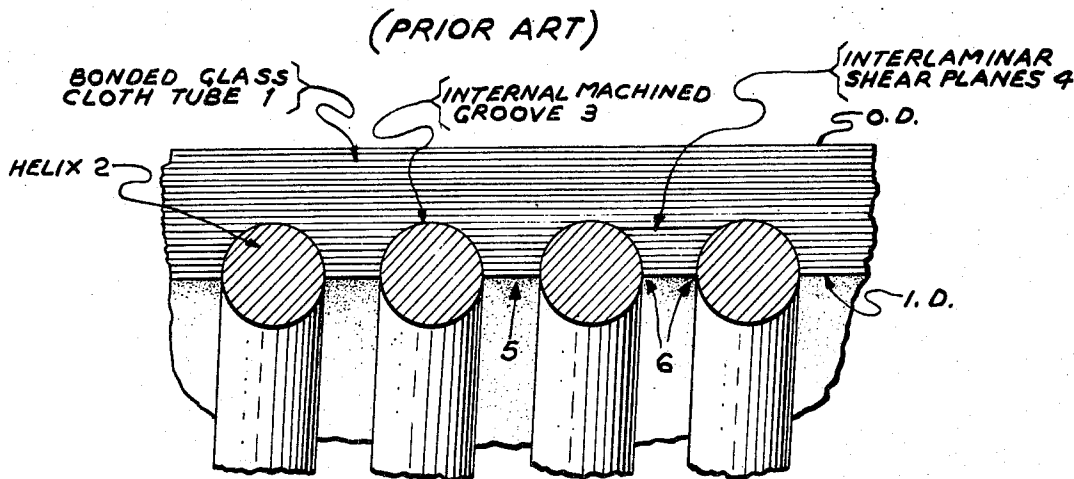
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Menotti J. Lombardi, Jr.

[57] **ABSTRACT**

This concerns the fabrication of an integrally-wound helix-coilform assembly for an antenna of, for example, the high voltage and high power tunable helix-cylinder (inductance/capacitance) monopole type. Preassembled on a collapsible, cylindrically-shaped mandrel are a wound helix of controlled pitch, an end coupling to which the helix is affixed at one end, and a binding post securing the other end of the helix wire. After the entire assembly is enclosed in a plastic covering such as teflon shrink tubing or adhesive-backed tape helically wound to a predetermined tension and pattern, cycloaliphatic epoxy resin-saturated glass fibers are wound in a carefully controlled manner over the entire assembly in a predetermined pattern and then cured. The tensioned plastic covering together with the controlled winding of glass fibers provides for the interlaminar shear faces of the coilform structure type to be formed as convolutions between the helix turns, thus giving rise to an integrally-constructed assembly far superior both structurally and electrically.

3 Claims, 9 Drawing Figures



SHEET 1 OF 3

Fig. 1
(PRIOR ART)

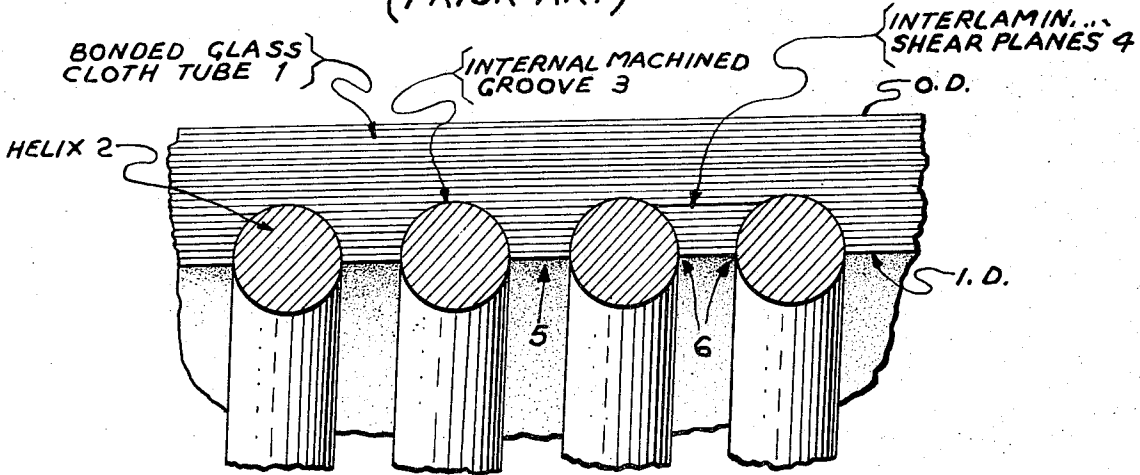


Fig. 2

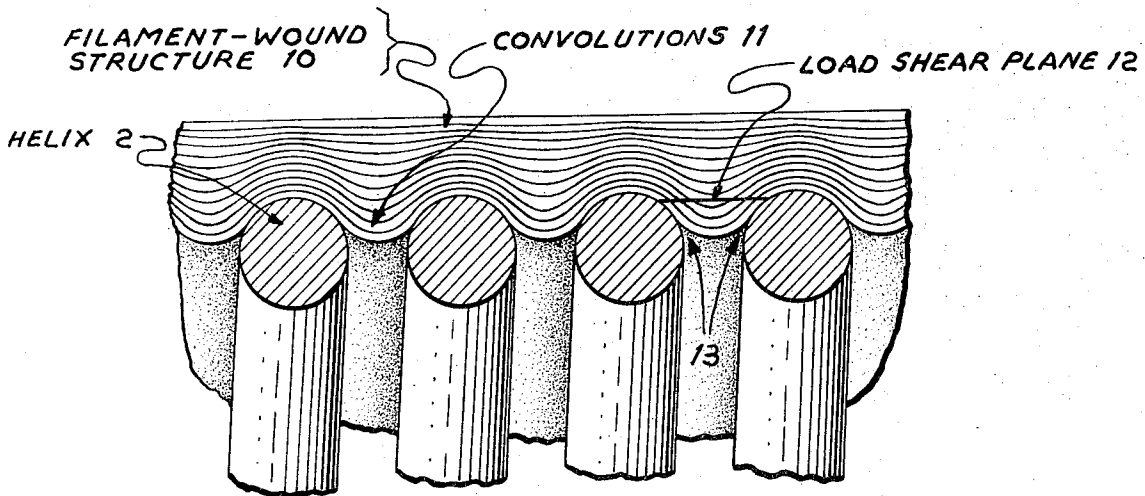
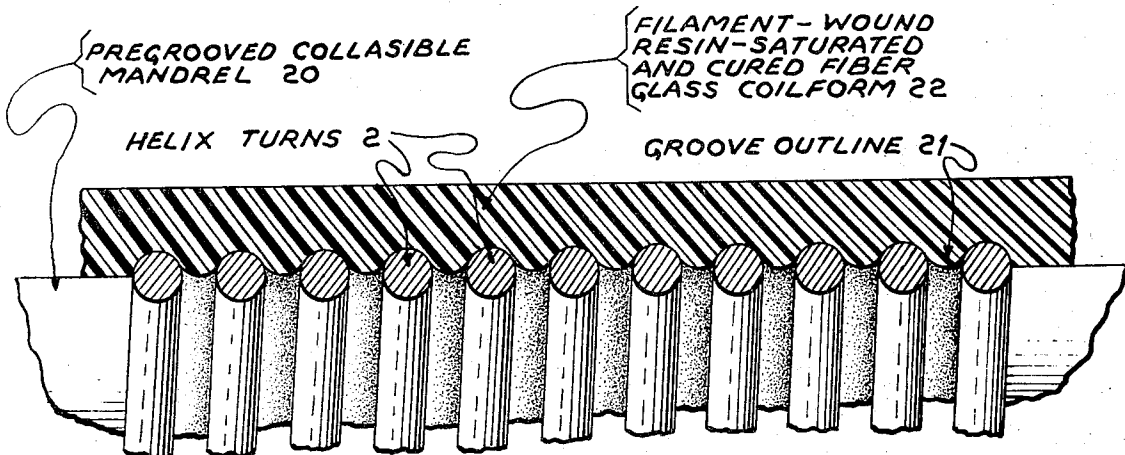


Fig. 3



SHEET 2 OF 3

Fig. 4A

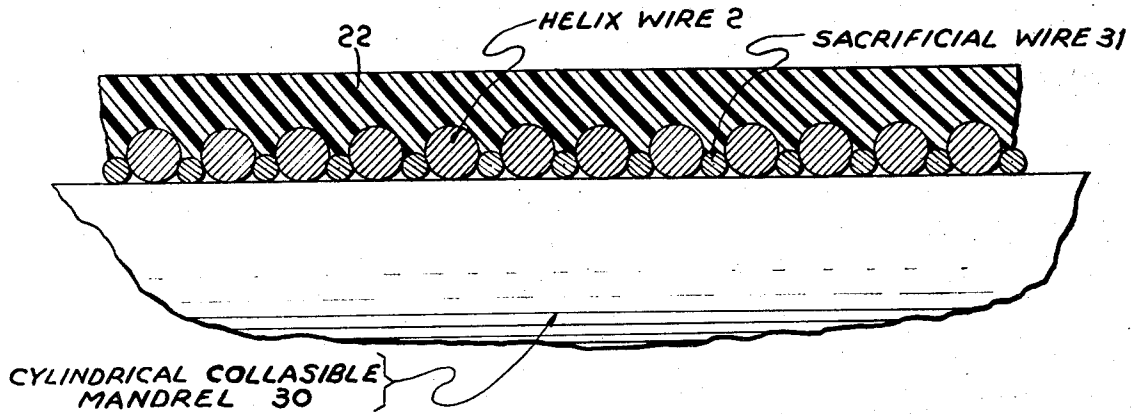


Fig. 4B

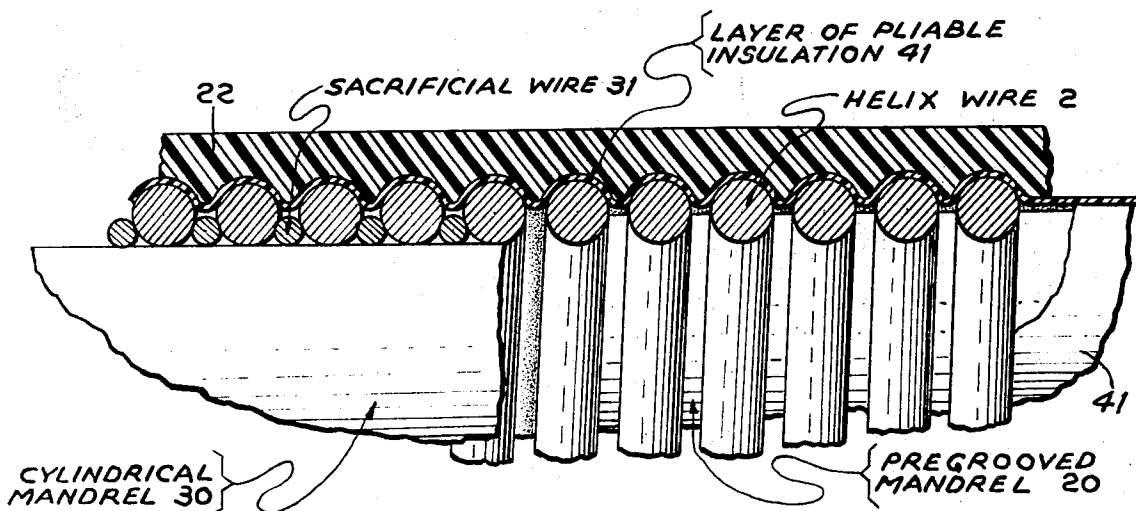


Fig. 4C

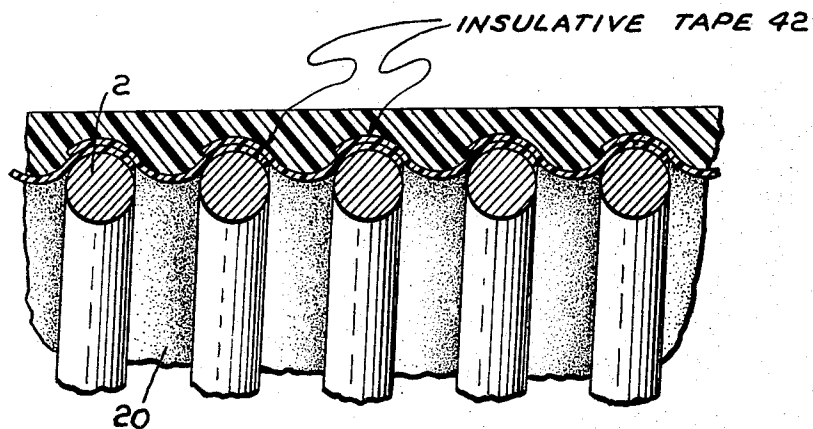


Fig. 5A

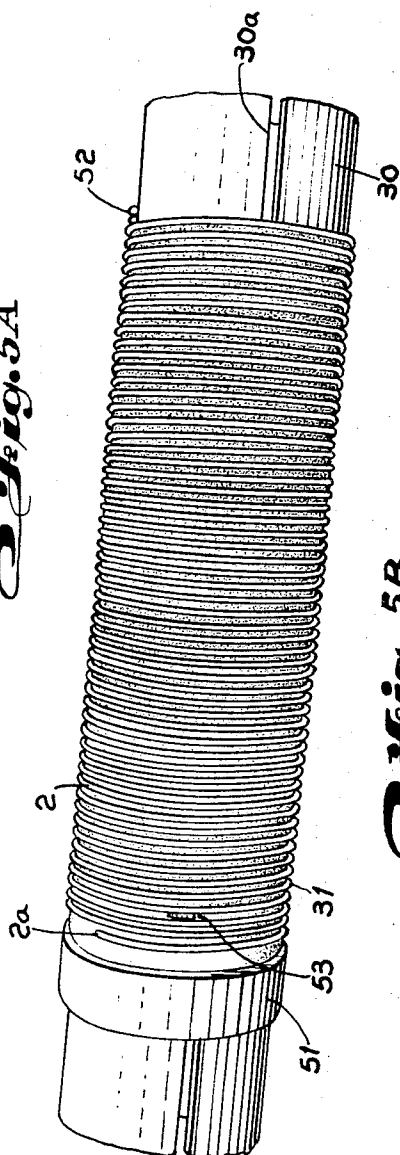


Fig. 5B

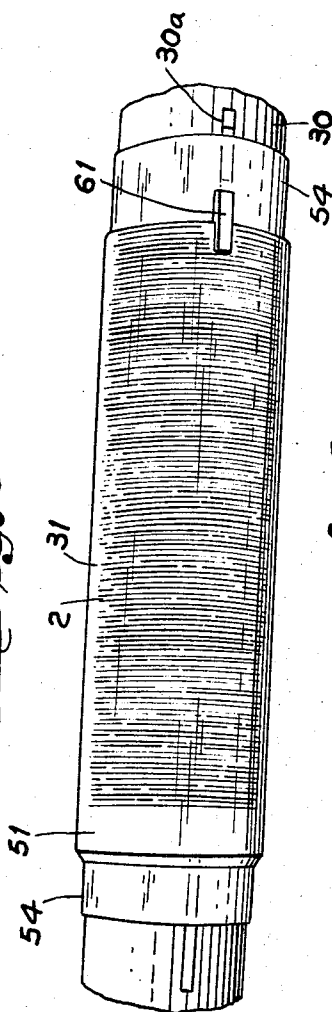
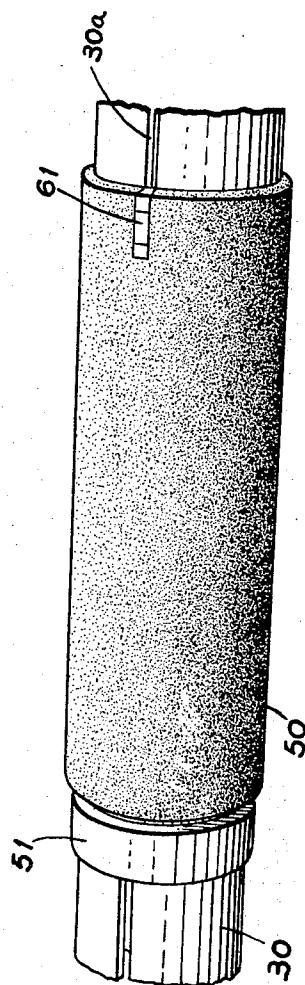


Fig. 5C



INTEGRALLY-WOUND ANTENNA HELIX-COILFORM

BACKGROUND OF THE INVENTION

This invention relates to antenna arrangements of the combined inductance/capacitance type wherein a helix and a cylinder are tunably coaxially arranged end-to-end, and more particularly to the helix-coilform assembly therein.

Such antenna arrangements are already known, and may be found in the following U.S. Patents/Applications: U.S. Pat. Nos. 2,781,514; 2,875,433; application Ser. No. 324,607 filed Jan. 18, 1973, which references, insofar as the disclosures thereof are pertinent to this invention, are incorporated herein by reference.

In these related prior-art tunable inductance/capacitance type antennas, which are operable in the 2 - 30 MHz range, and have particular application on submarines and on surface ships, the inductance element is by design a metal helix imbedded in an insulation coilform so as to expose the internal surfaces of the helix to a traveling "short" mechanism within the helix to effect a continuous tuning characteristic. For a number of practical reasons, this assembly of helix and coilform formally comprised a multiplicity of short coilforms machined from commercially available bonded-fiberglass tubing assembled end-to-end to produce the desired length, which short coilforms had to be assembled together along a common axis by an appropriate number of coupling pieces. A pre-wound metal helix would then be inserted, fitted and fixed to achieve the desired product. Such an arrangement is quite costly and has a number of disadvantageous features.

This arrangement may be replaced by an integrally-mounted helix-coilform as described herein and which is the principal object of this invention.

In the past, coilforms were machined from tubular stock of mandrel-wound epoxy-bonded or silicone-bonded fiberglass cloth. The choice of the resin system was controlled by the required electrical properties of the material. In the antenna systems contemplated to which the above-indicated references and this invention relate, the voltage may for example reach 30 KV, thus requiring that the electrical characteristics be extremely carefully considered. The maximum length of a section (of which several were needed to produce the coilform of required length) was limited by the machinery and the tools available to produce it. An internal thread in each section was machined so as to eventually receive the metallic helix into a cemented and pinned assembly of all required sections and connecting couplings. A metallic end coupling, threaded internally similar to the coilform sections, received and anchored the helix at one end. A binding post secured the other end.

Since in the prior art method of producing a coilform, an internal groove is machined into a bonded glass-cloth tube, the weakest planes in such a tube both physically and electrically are those produced by the concentrically bonded seams of wrapped cloth. The interlaminar shear strength here may be as much as 4,000 psi for epoxy-resin bonds and only 1,500 psi for silicone-resin bonds. Extreme care is required in order to prevent the delamination of material between the pitch of the grooves during machining. When delamination does occur, the repair is costly, time-consuming and

degrading, both structurally and electrically. These interlaminar surfaces between helix turns limit the load-carrying capacity of the helix particularly when the antenna is subjected to vertical shock. Intense concentration of electrical stress is experienced along the weak interlaminar shear planes between adjacent turns of the helix; thus the configuration and discontinuities in the material between helix turns substantially limit also the power-handling capacity of the helix because of the proportional steep voltage gradients possible between helix turns.

Of additional concern in the above-indicated prior art arrangements is the fact that a number of substantially rectangular apertures are required to be machined into each short coilform section for assembly purposes, which apertures were arranged longitudinally in a line. As a result of these apertures, the dielectric considerations between helix turns are substantially changed and present additional high voltage problems through the creation of steeper voltage gradients between the adjacent turns as a result of the coilform material/air dielectric interface. For a more detailed explanation of this phenomenon see the discussion of high voltage considerations relative to dielectric interfaces in U.S. Patent Application Ser. No. 327,266, filed Jan. 29, 1973. Moreover, the construction of these apertures through the wall of each short coilform section creates sharp edges which tend to considerably concentrate electrical stress, thus requiring lower operating power and potentials in order to prevent damaging high voltage creepage or corona breakdown.

It is, therefore, another object of this invention to provide an integrally-constructed helix-coilform arrangement which eliminates the drawbacks of the prior art.

In using the machined design of coilform, machined clearances and closely controlled interfaces must be provided for the metallic and coupling and tap lug. It is, therefore, a further object to provide an integrally-constructed helix-coilform arrangement in which such machining requirements are eliminated.

SUMMARY OF THE INVENTION

According to the broader aspects of the invention, there is provided an integrally-constructed helix-coilform arrangement (for use in, for example, high voltage RF antennas), comprising a helix formed of helix wire controllably wound in predetermined pitch, and a coilform structure comprised of resin-saturated fibers of dielectric material arranged in predetermined manner over said helix, the arrangement of said fibers providing formation of convolutions between helix turns, with this convolution structure substantially increasing both the shear load and power handling capacity of the helix-coilform arrangement.

Moreover, the invention further includes the unique method of constructing an integrally-wound antenna helix-coilform arrangement comprising the steps of assembling and securing a helix onto a removable working surface of predetermined configuration, and creating about said helix a coilform by winding resin-saturated fibers of dielectric material about said helix in predetermined manner, thereby effecting a coilform structure having convolutions between helix turns.

When affixed upon a collapsible mandrel, the end coupling receives the end of a preformed helix or the end of similar wire, each of which can be mechanically

fastened, soldered, or otherwise suitably affixed to it. After winding the helix with a controlled pitch through the use of either an externally-grooved mandrel or a sacrificial spacer wire on a cylindrical mandrel, the tail end of the helix is anchored to the mandrel with a specifically designed binding post that will eventually be incorporated into the coilform during its application over this assembly.

At this point, a shrinkable teflon or other suitable plastic tubing of proper thickness may be applied and shrunk over the entire assembly on the mandrel, or an adhesive-backed teflon or other acceptable dielectric tape of proper elongation, width and thickness may be helically wound with a predetermined tension over the entire assembly on the mandrel. The purpose of the teflon sleeving or tape is to permit the subsequent winding of resin-saturated glass fibers over the assembly in such a manner as to contain the fibers between the helix turns to a desirable configuration and to prevent seepage of uncured liquid resin from contacting the mandrel.

After winding resin-saturated glass fibers over the entire assembly of end coupling, helix and post mounted on the mandrel to the necessary helical and circumferential patterns and thickness so as to impart the desired structural strength, the resin is hardened by curing it. The hardened assembly is then removed from the collapsible mandrel and the coilform is trimmed by machining it to a proper diameter and length.

BRIEF DESCRIPTION OF THE DRAWINGS

The above-mentioned and other objects and features of this invention will become more apparent and the invention itself will be best understood by reference to the following description taken in conjunction with the accompanying drawings, in which:

FIG. 1 is an enlarged fragmentary, sectional side view of prior art helix-coilform construction;

FIG. 2 is an enlarged fragmentary sectional side view showing in a general way the helix-coilform construction according to the invention;

FIG. 3 is a fragmentary sectional side view illustrating a first preferred method of construction of the integral helix-coilform assembly according to the invention;

FIGS. 4A-4C are fragmentary sectional side views showing alternative preferred construction techniques of an integral helix-coilform assembly according to the invention; and

FIGS. 5A-5C illustrate sequentially in prospective views the helix-coilform assembly in various stages of construction in accordance with the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

As stated hereinbefore, the prior coilform arrangements, as represented by the enlarged fragmentary cross-sectional illustration of a helix-coilform arrangement in FIG. 1, are machined from tubular stock of mandrel-wound, epoxy-bonded or silicone-bonded fiberglass cloth, with several sections thereof being required to be coupled together by way of external connecting couplings (not shown). Each section 1 of bonded glass cloth tube is internally threaded and mated by orientation so as to eventually receive the metallic helix 2 into a cemented and pinned assembly of all the sections and connecting couplings required to obtain the necessary assembly length. To this is added

a metallic end coupling (not shown) which is threaded internally in like manner to the coilform sections, and which receives and anchors the helix at one end. The other end of the helix is secured to a binding post (also not shown) which is rigidly mounted in the end section of the coilform arrangement.

In FIG. 1, an internally machined groove 3 in a wound and bonded glass cloth tube coilform section, the inner and outer diameters thereof being represented by ID and OD respectively, which receives the helix 2 creates severe high voltage as well as handling problems. The weakest planes in such a structure both physically and electrically are those produced by the wrapped cloth, represented in FIG. 1 as accentuated parallel lines 4 between adjacent helix turns. In considering these weak interlaminar shear planes 4, it is to be noted that the shear is coincident with the bond planes. The interlaminar shear strength here may approach as much as 4,000 psi for epoxy-resin bonds and only 1,500 psi for silicone-resin bonds. However, these are limitations which require that extreme care must be taken in order to prevent the delamination of material 5 between the pitch of the groove 3 during the internal machining thereof in tube sections 1. If delamination occurs at any time (though usually occurring during machining of the groove 3) repair is mandatory. Such repair is costly, time consuming and very degrading, both structurally and electrically. The interlaminar surfaces between helix turns limit the load carrying capacity of the helix when the antenna is subject to vertical shock, i.e., axially to coilform. The bond planes, moreover, tend to create potential unwanted paths for current flow whenever substantial potential difference is experienced between adjacent helix turns. A further natural disadvantage of this arrangement, resulting specifically from the internally machined groove, is that sharp edges are derived at the ID surface, see for example at 6. From the discussion of such structural configurations relative to very high voltage considerations as given in copending U.S. Patent application Ser. No. 327,266 above-mentioned, it is quite apparent that whenever there exists substantial potential difference between adjacent helix turns, there results an intense concentration of electrical stress at these edges. The sharp discontinuity provided by each sharp edge so effects the potential created thereat as to seriously lower the dielectric efficiency of the fiberglass cloth tube 1 and surrounding air, and thereby resulting in a reduced power handling capability.

In the helix-coilform construction according to the invention, as represented generally by the enlarged fragmentary cross-sectional illustration of FIG. 2, the helix-coilform is fabricated on a collapsible mandrel (shown in FIGS. 3-5). A metallic end coupling (not shown in FIG. 2) is affixed on the collapsible mandrel and receives the end of the helix wire 2, the latter in turn being wound on the mandrel in controlled pitch and secured at its other end to the mandrel. In the instance fabrication of a coilform, the helix groove is formed during a filament winding process on the helix 2 arranged on the collapsible mandrel in which the orientation and distribution of fibers is controlled to form the filament wound structure 10 in FIG. 2. This method of fabrication eliminates the costly and degrading machining operation of the prior art, inasmuch as the tension applied to the fibers during the winding process over the mandrel-mounted helix creates a smooth natu-

ral grooving. Eliminated also by this fabrication are the cylindrical laminate shear faces or planes 4 of the prior art (FIG. 1). Rather, the interlaminar shear faces are formed as convolutions 11. The load shear planes, represented by designator 12 in FIG. 2, in relation to the filament structure 10 are such as to have the shear loads carried across the convolutions 11; that is, the load shear planes cut across glass fibers. Thus, the shear loads are no longer dependent upon interlaminar shear capacity, but upon the considerably higher shear capacity across glass fibers.

The fabrication of a helix-coilform assembly according to the invention, as represented in FIG. 2, moreover, substantially improves power handling capabilities particularly in a helix-cylinder type antenna application by the electrically more suitable structure provided as to high voltage considerations. Gone are the sharp edges formed from the internal machining step of the prior art. In their place rounded discontinuities 13 between coilform and helix. As a result there is a more gradual discontinuity giving rise to a considerably more favorable distribution of the electric field, resulting in turn in much lower electrical stress. Thus, it is seen that the fabrication of a helix-coilform arrangement according to the invention presents substantial improvement over the prior art both structurally and electrically.

Referring now to FIGS. 3-5, there is illustrated various modes of helix-coilform fabrication according to the invention. A first method of fabrication may be understood from the fragmentary cross-sectional illustration of a helix-coilform assembly in FIG. 3, wherein a pre-grooved mandrel 20 is shown having a formed grooving or groove outline (at 21) to impart the desired configuration to the dielectric convolutions between helix turns 2 which properly locates and holds the helix in the correct pitch, etc. Resin saturated glass filaments are then wound between and over the helix turns in programmed circumferential and helical patterns as desired. This is then cured in well known manner to form the filament-wound resin-saturated and cured fiberglass coilform 22 illustrated in FIG. 3. Following curing, the outside diameter of the coilform 22 is machined to appropriate size either while upon or after removal thereof from the collapsible mandrel.

Another mode of fabrication may be seen in FIG. 4A, in which is shown in yet another fragmentary cross-sectional view the use of a cylinder, i.e. a cylindrical collapsible mandrel 30 conforming to the required inside diameter of the helix 2, which cylinder may be utilized where the cost of a pre-grooved collapsible mandrel may be prohibitive. In this instance the proper pitch is controlled by applying along with a helix wire 2, in the winding thereof around the mandrel 30, a sacrificial wire 31 of proper cross-sectional diameter to provide the desired convolution structure between helix turns. If greater pitch is desired, it may be appreciated that two or more sacrificial wires 31 may be wound side-by-side along with the helix wire 2. Once again, after the helix wire 2 is properly wound on the mandrel 30, the filament-wound resin-saturated and cured fiberglass coilform 22 is fabricated as described above with reference to FIG. 3. Upon curing of the coilform 32 and collapsing the mandrel 30, the sacrificial wire may then be removed, leaving the final helix-coilform assembly to be machined or trimmed to appropriate diameter and length.

It may occur, however, in the above-discussed fabrication that the resin will seep between the helix and sacrificial wire and will either produce unwanted "flash" that may be troublesome to remove, or bind the sacrificial wire to cause troublesome removal therefrom, or produce undesirable sharp edges where least desired in times of high voltage breakdown, i.e. between helix turns.

To prevent all of the above potentially undesirable possibilities, a thin layer of pliable insulation 41, such as teflon, may be applied over the helix and the sacrificial wire as shown in FIG. 4B. Here, there is illustrated the use of the layer of pliable insulation 41 in both a pre-grooved collapsible mandrel configuration 20 and the alternative cylinder collapsible mandrel configuration 30. This layer of insulation 41 may be in the form of shrinkable plastic tubing, (e.g., thin irradiated teflon) or in the form of insulative tape (e.g., thin teflon tape) applied as an overlapping winding conforming to the pitch of the helix. This latter embodiment may be seen in FIG. 4C wherein the tape 42 is shown wound over and between the helix turns 2 in overlapping fashion, with the helix wire itself being wound on a pre-grooved mandrel 20.

The teflon sleeve 41 may be etched on its external surface to effect adhesion to the resin. The teflon tape 42 with an adhesive backing may be wound to seal its same with the adhesive side out, in serving the same purpose. It may be appreciated that the thickness and the value of the elongation as well as the magnitude of winding pull controls the depth of the free convolution that is formed by the tape. Similar considerations are made with regard to the shrink tubing. The sacrificial wire, or form of groove on the mandrel, of course, also contributes to the general shape and depth of the convolution to which the insulation is distorted during the winding or shrinking process.

FIGS. 5A-5C illustrate in perspective views successive stages of fabrication of the helix-coilform arrangement according to the invention, particularly employing the use of a sacrificial wire. FIG. 5A shows a collapsible cylindrical mandrel with at least one longitudinal slot 30a therein, having in addition to providing for collapsibility of the mandrel a second purpose to be referred below. As stated hereinbefore, an end coupling 51 is affixed upon the collapsible mandrel 30. This end coupling 51 receives the end 2a of either a preformed helix or the end of similar wire, either being magnetically fastened or soldered to the end coupling 51. After winding the helix with a controlled pitch through the use of either a pre-grooved (externally) mandrel or a sacrificial spacer wire (as illustrated in FIGS. 5A and 5B), the tail end of the helix 2 is anchored to the mandrel 30 by way of a binding post to be positioned at 52 which will eventually be incorporated into the coilform during its application over this assembly. It is to be noted that the beginning of the sacrificial spacer wire 31 has its origin at 53 wherein the end thereof is tucked into the interior of the mandrel through slot 30a. As shown, spacer wire 31 ends with helix wire 2 at point 52.

At this time in the construction sequence, the shrinkable teflon or other suitable plastic tubing 54 of proper thickness may be applied (and shrunk) over the entire assembly on the mandrel, or the adhesive-backed teflon or other acceptable plastic tape of proper elongation, width and thickness may be helically wound in the

pitch of the helix with a predetermined tension over the entire assembly on the mandrel. As indicated above, a specific purpose of the teflon sleeving or tape is to permit the subsequent winding of resin saturated glass fibers over the assembly in such a manner as to contain the fibers between the helix turns to a desirable configuration and to prevent the seepage of uncured liquid resin from contacting the mandrel.

A tap lug 61 (FIGS. 5B and 5C), secured to the helix wire a few turns from the one end of the helix is also shown incorporated into the pre-wound filament assembly. The function of this tap lug 61 is to provide the input point for transmission energy to be applied to the helix portion of the helix/cylinder type antenna arrangement; a greater functional understanding of the element may be gained from the hereinbefore-mentioned reference U.S. Patent application Ser. No. 324,607. Element 61 is shown in FIGS. 5B and 5C as an insulated tap lug attached and soldered to the helix at a predetermined location corresponding to impedance matching characteristics of the antenna.

Following the application of pliable insulation, resin-saturated glass fibers are wound over the entire assembly of end coupling 51, helix 2, and post 61 mounted on the mandrel in the necessary helical and circumferential patterns and to the proper thickness so as to impart the desired structural strength, etc. The resin is then hardened by curing it to form the coilform 50 as shown in FIG. 5C. The hardened assembly is then trimmed by machining to its proper diameter and length.

There are many types of resins available for bonding glass fibers, each providing its own particular properties to the bond produced. Those most often used for purposes similar to this invention are epoxy resins which impart excellent structural and machining properties, but relatively poor electrical properties. The dielectric constant at 1 MHz for the epoxy products are in the order of 5.0 and the dissipation factor 0.020, while the equivalent dielectric constant for the silicone products are in the order of 4.0 and the dissipation factor 0.003. Because of the physical properties of the silicone resin during application, it is not generally used in the filament winding process.

Resin systems that impart excellent structural, temperature and arc-resisting properties, but yet possess reasonable electrical loss properties, are the cycloaliphatics. The coilform shown in FIG. 5C is intended to be bonded with a cycloaliphatic epoxy. Cycloaliphatic epoxies are currently used in applications where high performances are required such as filament winding, potting and encapsulating, and the casting of high voltage bushings and insulators. The cycloaliphatics all give superior strength and electrical properties at elevated temperatures, thus providing favorable characteristics in the antenna assembly for which the helix-coilform

integral arrangement is intended.

There has been discussed herein the fabrication of an integrally wound helix-coilform assembly for an antenna of for example the helix/cylinder (tunable inductance/capacitance) type. On a collapsible mandrel of substantially cylindrical shape there is affixed an end coupling to which is secured one end of a helix wire. The helix wire is wound onto the mandrel in a carefully controlled pitch and secured at its other end by a binding post. Substantially the entire assembly of mandrel, helix and end coupling is enclosed in a suitable dielectric cover of predetermined tension, either teflon tape or shrink tubing. Cycloaliphatic epoxy resin-saturated glass fibers are then wound over the entire assembly in predetermined helical and circumferential patterns and then cured to form the completed coil-form structure. The tensioned dielectric covering together with the controlled winding of glass fibers causes the dielectric structure to take the form of convolutions between helix turns, thus giving in this integral assembly structural and electrical properties far superior to the prior art, while eliminating costly machining techniques etc. It is seen that the machining of grooves for the helix and holes for posts is eliminated since the coilform is wound immediately over the preassembled components and secures them without the need for additional hardware.

While the principles of this invention have been described above in connection with specific apparatus, it is to be understood that this description is made only by way of example and not as a limitation on the scope of the invention as set forth in the objects and features thereof and in the accompanying claims.

What is claimed is:

1. A helix-coilform arrangement for high voltage antennas of the type having internally-accessible helix windings comprising:

a. a hollow-core helix formed of helix wire controllably wound in a predetermined pitch; and

b. a coating of resin-saturated fibers of dielectric material on the outer surface of said helix, said dielectric material forming convolutions between the turns of said helix to provide a stress-free dielectric covering for said helix, whereby said helix and covering form an integrally-constructed helix-coilform structure.

2. The arrangement of claim 1 wherein said dielectric covering comprises epoxy-saturated glass fibers having a smooth and continuous interface between the glass fibers of the coating and the turns of the helix.

3. The arrangement according to claim 2 further comprising a layer of heat shrinkable plastic intermediate the turns of said helix and said epoxy-saturated glass fibers whereby said epoxy is prevented from direct contact with said helix.

* * * * *