July 23, 1968 R. P. LAMONS 3,394,400

CORRUGATED SHEATH COAXIAL CABLE WITH WATER-SEALING BARRIERS AND METHOD OF MAKING SAME

Filed Oct. 22, 1965 2 Sheets-Sheet 1

FIG. 2

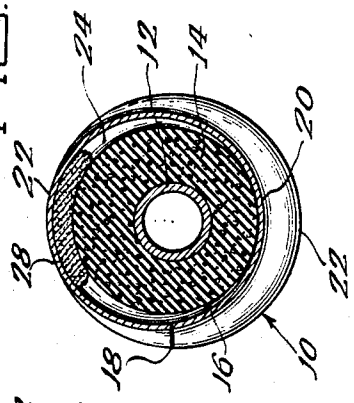


FIG. 1

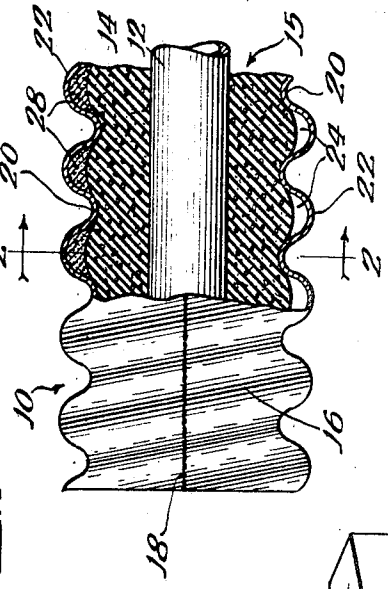


FIG. 3

Inventor:
Robert P. Lamons
By Leonard Nieman
Attorney

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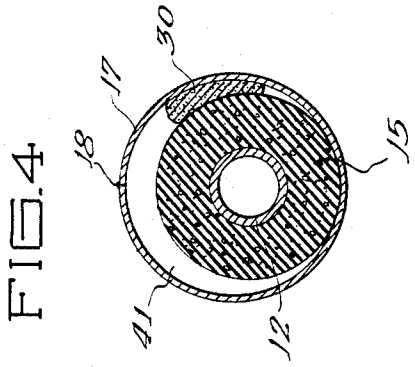


FIG. 4

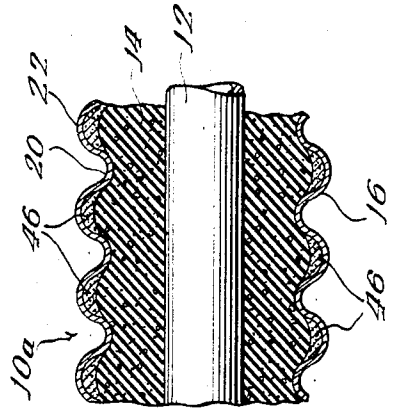


FIG. 5

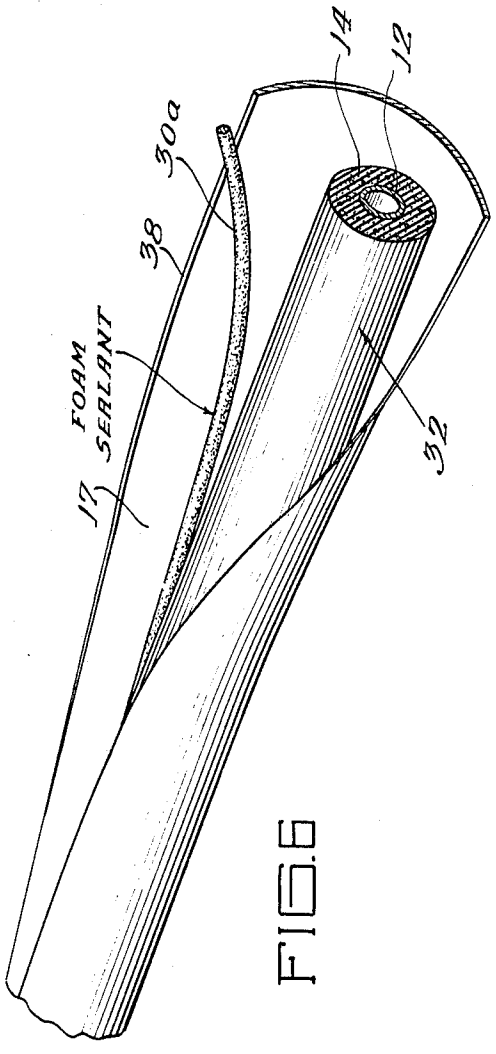


FIG. 6

Inventor:
Robert P. Lamons
By: Leonard Mieras
Attorney

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Patented July 23, 1968

3,394,400

CORRUGATED SHEATH COAXIAL CABLE WITH WATER-SEALING BARRIERS AND METHOD OF MAKING SAME

Robert P. Lamons, Hinsdale, Ill., assignor to Andrew Corporation, Orland Park, Ill., a corporation of Illinois

Filed Oct. 22, 1965, Ser. No. 501,366
16 Claims. (Cl. 174—102)

ABSTRACT OF THE DISCLOSURE

The effects of water-leaks in a foam-dielectric corrugated cable are reduced by confining water entering the corrugations to the region of entry. This is accomplished by depositing a viscous sealant material in a longitudinal mound along the foam dielectric of the cable and then corrugating the outer conductor, thereby forming a barrier to longitudinal migration of water.

This invention relates to sheathed cable, and more specifically to cable of the type having one or more inner conductors embedded in an insulator sleeve or sheath, with an outer conductor corrugated about the insulator sheath. The invention is of particular advantage in connection with foam-dielectric coaxial cable for use at high frequencies.

The invention is herein described as applied to the type of coaxial cable construction described in U.S. Patent 3,173,990 of the same inventor, in which it is particularly advantageous, but will be seen to be also applicable to other cable constructions wherein the improvement afforded may be advantageously utilized.

In the commercial manufacture of such coaxial cable, there is first made, in some conventional manner, a core of a foamed dielectric bearing the inner conductor. The outer conductor is placed or formed around this core in the form of a simple tube and then helically corrugated. Since the tube is usually somewhat larger than the core before the corrugation step, this process of manufacture normally leaves a void in the internal crest of the helical corrugation. In the above-mentioned patent, there are described features of construction by which such cables are made free of differential expansion of the inner and outer conductors, thus making it unnecessary to employ special end-connectors for the purpose of withstanding differential expansion forces in long cable runs. Such connectors of course have no provision for sealing against moisture. The undesirability of permitting entry of moisture or water into the helical void has long been recognized, and small dabs or plugs of grease or similar substance are often used to plug up the ends of the helical void in the corrugation crest of the cable, both in reel storage of bulk cable and in installing connectors.

The maintenance of a water-free condition of the interior of a cable so constructed is of course also dependent upon the integrity of the seal effected by the outer conductor itself. Such integrity against the entrance of water or moisture is not easily obtained where the outer conductor is formed with a seam which is welded after the conductor is formed to tubular shape around the core. The maintenance of complete water-tightness of the weld against small leaks in continuous cable-making processes is of substantial cost both as regards technique of manufacture and as regards necessity for testing and inspection. Furthermore, of course, any puncture occurring in use opens the helical void to water.

It has been found that under certain conditions, such as a water leak at an elevated point in a long cable run, serious damage may result, and it is the object of the present invention to provide a satisfactory manner of substantially eliminating such possibilities.

It is of course theoretically possible to construct such a cable with the helical void in the crest eliminated, by having the foamed core material occupy the entire crest. From the practical standpoint, however, this cannot be readily done, for a number of reasons. With known practical corrugation processes, the internal crest or maximum diameter cannot be made substantially less than the internal diameter of the uncorrugated tube prior to the corrugation. Accordingly, such a fully filled crest can be produced only by an extremely tight fit of the tubular outer conductor on the dielectric sheath prior to corrugation. The difficulty of producing such a fit, particularly in cables of large diameter and particularly where welding must follow, is great. In practice, it is found that this difficulty is made even greater by the variables encountered in practical processes for forming the foam core, which is normally made by extruding the resinous dielectric on a center conductor, the foaming occurring after this extrusion by incorporating a foaming agent in the extruded resin. The holding of close tolerances in the outer diameter of such a core is highly impractical. An additional practical consideration in such an approach to the moisture leakage problem lies in the reduction of flexibility which may result from such a filling in the helical crest; obviously, the seriousness of this aspect depends greatly on other design parameters, such as the material, thickness, corrugation depth, etc., of the outer conductor and the compressibility, etc., of the particular dielectric.

Prior to the present invention, the only measures known to have been employed for assurance against the effects of such leaks were precautions against their occurrence, all of substantial cost. In addition to monitoring complete soundness of the weld, it was considered necessary to design outer conductors for mechanical strength sufficient to assure, to the fullest reasonable extent, against any penetration whatever in use, and protective jackets were frequently added even though they might not otherwise be required. Not only do such precautions involve substantial cost, but in addition assured water-tight integrity of the outer conductor in use, particularly against abrasion, etc., involved substantial sacrifice of flexibility due to the strength and thickness of the outer conductor required for such assurance.

The present invention provides a construction in which the benefits obtainable from elimination of the void by employing a core of a size filling the crest after corrugation (even were such a construction readily produced) with the dielectric which bears the inner conductor are obtained in a simple and highly practical manner without the sacrifice of flexibility produced by such a construction. In the cable construction of the invention, a moisture or water barrier of a material other than the dielectric itself is employed in the helical crest. This material is selected and added in a manner such that there is no substantial complication whatever of the process of manufacture, either by way of addition to the strictness of dimensional tolerances of the core or otherwise. This is accomplished by interposing between the core and the outer conductor, prior to corrugation of the latter, a sealant material which yields very readily under the corrugation pressure, as compared with the material of the dielectric core, so that the addition of the sealant or barrier material has substantially no effect upon the ultimate configuration resulting from the corrugation operation. There accordingly results, after the corrugation, a construction substantially identical to that obtained prior to the present invenion, except for the addition, in the void heretofore appearing, of a sealant preventing migration of water or moisture.

The invention achieves the desired result with greatest simplicity in the continuous-process manufacture of cable, in which the tubular outer conductor is continuously formed around the core from uncoiled flat sheet mate-

rial, the seam thus formed by the edges then being welded to form a closed tube, which is then corrugated. The material of the sealant barrier of the present invention is readily inserted before the closure of the conductor sheet to the form of the tube. This barrier or sealant material may be dispensed or fed in a similarly continuous manner to any circumferential region of the anular interface between the core and the tube being formed. When the tube is subsequently corrugated, the sealant material blocks the passage of water through the helical clearance or void in the corrugation crest. The configuration of the portions of the cable other than the sealant is substantially entirely unaffected by reason of the ready yielding of the sealant under the corrugation pressure. Furthermore, this same yielding characteristic of the sealant material eliminates the impairment of flexibility which would result from filling the void with a relatively rigid and unyielding body of material. Preferably, the yielding properties of the sealant material are imparted by employment of a viscous deformable liquid-solid such as a grease or wax. However, as will hereinafter be seen, other forms of sealant, such as readily compressible foam plastics, may be employed if desired.

Persons skilled in the art may readily practice the broader aspects of the invention from the brief description thereof above. However, both for the purpose of describing certain narrower aspects of the invention, and for the purpose of illustrating and describing preferred embodiments as required by the patent laws, reference is now made to the embodiments of the invention shown in the attached drawing, in which:

FIGURE 1 is a view partially in side elevation and partially in longitudinal section, of a cable made in accordance with the invention;

FIGURE 2 is a transverse sectional view taken along the line **2—2** of FIGURE 1;

FIGURE 3 is a more or less schematic view illustrating the method or process of manufacture of the cable of FIGURES 1 and 2;

FIGURE 4 is a transverse sectional view taken along the line **4—4** of FIGURE 3, illustrating the cable at an intermediate stage of manufacture;

FIGURE 5 is a sectional view of a modified form of the cable of the invention; and

FIGURE 6 illustrates a further variant of the method or process aspect of the invention.

The invention is illustrated in the drawing and described below as applied to the construction of a coaxial cable of the type shown in U.S. Patent 3,173,990 of the same inventor. The cable **10** has an inner conductor **12** (here shown as a hollow tube) encased or embedded in a foam dielectric **14** to form a cable core assembly **15**. This is encased or sheathed in a corrugated tubular outer conductor **16**, formed from a sheet or strip **17** of suitable material such as copper, welded at **18**. The roots **20** of the helical corrugation are in compressive contact with the outer surface of the core **15**. However, the crests **22** of the corrugations are substantially spaced from the foam dielectric sleeve **14** constituting the outer portion of the core **15**, thus leaving a helical void which is primarily circumferential in direction, but has a longitudinal component imparted by its pitch, so that there is formed a continuous passage all along the cable, even though the compressive contact of the corrugation roots with the foam forms a water enclosure at the sides of the passage, preventing substantial direct longitudinal flow.

As thus far described, the cable of FIGURES 1 and 2 represents a construction existing prior to the present invention, commercially manufactured under the trademark "Heliax," employing a dielectric or insulator **14** of foamed polyethylene. For the reasons described in the patent mentioned above, this type of cable has found widespread use in communications systems and similar applications where the combination of relatively low cost and high electrical performance which it affords are advantageous. By its nature, much of the use for such cable is in long outdoor runs, as in the connection of remote antennas and similar uses. The considerations of economy which make the use of higher-cost cables, such as air-dielectric cables, impractical for most such uses at the same time make it impractical that there be a high degree of care used in handling and installation of the cable. Furthermore, in many installations the cable is subject to abrasion in use, as, for example, where some object may be repeatedly blown against it by the wind. In the event of the appearance of a leak in the outer conductor, entering water will run down the helical void and become standing water in the lowest part of the cable. If the lowest part of the cable run is at an end connector, as common in connecting a transmitter to a tower-mounted antenna, for example, the entering water may appear in the electronic equipment to which the cable is connected, and may not only short the cable but cause other severe damage.

The problem just mentioned may of course be dealt with in various manners known in connection with other types of sealed transmission lines, such as the provision of special drain fittings, etc. accompanied by the use of sufficiently thick and durable outer conductor construction to assure leakage integrity against all normally expected abrasions and rough handling, with or without the protective jackets frequently used for this purpose.

The problem of dealing with water leakage as so far described is generally similar to that long known in connection with cables of the type normally called "air-dielectric," in which the end-to-end passage for water entering through a leak is provided by the "air-dielectric" i.e., the region between the inner and outer conductors, of which only a small portion is occupied by the rigid insulating body employed to support the inner conductor within the outer. Prior to the present invention, the manners of dealing with the problem were analogous to those used for the same purpose with air-dielectric cables, as just described.

However, it is found that in fact the effects of water leakage on a cable of the present type are in the main substantially different from the effects of water leakage on a cable of the air-dielectric type, being much more severe in certain respects, but being of a nature to permit substantial elimination of the problem in a very simple manner.

Understanding of the present invention will be facilitated by considering the difference in effects of water ingress not only on air-dielectric and foam-dielectric cables using such a corrugated outer conductor but also on such a cable employing a solid dielectric such as solid polyethylene. Such a dielectric has a slow but finite moisture transmission; however, it has negligible moisture content even in its saturated condition. Thus the effects of a water leak in the sheath of a solid-dielectric cable are relatively negligible as regards electrical performance, provided that the dielectric remains free of cracks or fissures and a "trap" or drain prevents the water from reaching the ultimate end of the cable. In the case of the air-dielectric coaxial cable (as in a waveguide), the considerations are similar, except for the effect of water vapor in the region between the conductors, which will of course affect the dielectric constant and breakdown voltage appreciably.

In the case of foam, however, the moisture penetration properties of the foam are found to create a type of problem which does not exist with either of the other constructions. A foam plastic of the type used for these purposes will not, when unimpaired, be rapidly penetrated by moisture, since the gas bubbles or pores produced in the foaming action are in general of the closed-wall type. But the slow diffusion of water through the lattice of cells can ultimately produce a moisture content drastically increasing the dielectric loss of the foam material, particularly when the cells contain a residue of foaming or gassing agent with which the moisture interacts, as is

normally the case. When a substantial length of the dielectric is exposed to external water, the cable performance will be regraded. However, the rate of moisture penetration is so slow that confinement of the external exposure to water to one longitudinal point is found to prevent the appearance of any substantial impairment of overall performance of a long cable for very extended times; a cable of the order of 100 feet in length, for example, is found to be capable of fully satisfactory performance as regards dielectric losses for a period of up to a year or so with one small region exposed to water, while comparable losses would be produced in a day or so with exposure along the entire length. Where exposure to water is intermittent, as in seasonal weather conditions, the confinement of the region of exposure can prevent any serious problem whatever from occurring as a result of development of a leak.

In addition, it will be seen that at any point at which there may be an imperfection in the dielectric, either in the original process of making or as a result of exposure to temperature cycles, bending cycles, or combinations of these, exposure to water at that point may produce full penetration of the dielectric by the water. The likelihood of such an occurrence is of course greatly reduced by confining its possibility to cases where the crack or similar fault in the dielectric is at the same longitudinal point as the water leak in the sheath. Since this type of hazard is not confined to foam, the invention in its broader aspects may be employed advantageously with solid-dielectric cable.

In the construction shown in FIGURES 1 and 2, each turn of the helical void **24** is blocked by a barrier **28** of a suitable sealant material **30**. Water entering through a leak in any turn is confined to the void in that turn and cannot flow down the passage. Any water penetration of the dielectric which occurs is localized, and the effects on the electrical performance are limited to the very slight effect produced by the water in the outermost region at this localized point.

FIGURES 3 and 4 show the method of making the structure of FIGURES 1 and 2 in a continuous process. The process is shown highly schematically in FIGURE 3, since the equipment employed may be of any conventional type.

As indicated by the arrow in FIGURE 3, the steps of the continuous manufacturing process illustrated occur in the order showing as right to left in the drawing, the components moving in this direction. The conductor sheet or strip **17**, of copper or aluminum, is fed from a roll (not shown) and the core **15** may be fed from a reel after being earlier fabricated or may be fed directly from an earlier point at which the sheath **14** is formed and foamed on the conductor **12**. The sealant material **30** is deposited on the inner surface of the strip **17** just before the latter enters the forming tools **34** which produce its ultimate tubular form. The sealant material is deposited by a dispenser nozzle **35** at a point substantially displaced from either of the edges **36** or **38** of the strip **17**.

In the drawing, the forming tools **34** are illustrated merely as consisting of rollers **40** and a circular die **42**. As shown in FIGURE 4, the closure of the strip **17** to tubular form compresses or "squashes" the sealant material **30**, but the point of deposition of the sealant material is sufficiently removed from the welding point **18** so that this material does not interfere with proper making of the weld by the seam-welder schematically shown at **43**. When the corrugation is performed at **44**, the sealant material is further deformed by being squeezed out from the region of the roots of the corrugations into the crest region, so that the arc or angular region occupied by the sealant material is again further increased. The ultimate angular arc in which each turn of the passage is blocked is of course variable with the exact diameter of the core prior to extrusion, which of course varies the clearance or annulus **41** shown in FIGURE 4.

Preferably, the material employed as the sealant is a viscous semi-solid such as a grease or wax. Such a sealant may be heated or melted in dispensing to facilitate the process. In FIGURE 6, there is shown an alternate form in which the sealant **30*a*** is itself a foam plastic strip. In such a case, of course, the sealant strip should be substantially more yielding than the material of the dielectric, in order that the latter not be deformed from circular symmetry when the closure and corrugation are made. However, this relationship of the properties of the materials is critical primarily at the time of completion of the processing. Accordingly, a plastic may be employed for the sealant which is deposited prior to solidification and solidifies only after the corrugation is performed. Such a sealant may be dispensed at **35** with a gassing agent of the type used for foaming, and the barrier may be finally formed by foaming expansion within the void formed in the corrugation operation.

FIGURE 5 shows a construction in which the entire helical passage is filled. Where a viscous sealant is used for such a construction in manufacture by the method described, provision must of course be made for adjusting the feed rate of the sealant in accordance with any small changes in core size or other variables affecting the volume of the corrugation crest void, or to dispose of any excess sealant feed. In general, complete filling of the void with such a sealant is accordingly less desirable than the once-per-turn barrier earlier described where the insertion is made in this manner. However, where the sealant is a plastic foamed in situ, the problem of matching feed rate to void volume is avoided, since the degree of foaming occurring before solidification will automatically follow changes in the volume of the void.

It will be observed that bending of the cable is not substantially impeded by the barrier material, because of its ready yield. Where a viscous material such as grease or wax is employed, it simply redistributes itself in the region of the bend. Where the relative yielding is obtained by compressibility, as in the case of a soft spongy foam, no motion or flow of the sealant occurs, but the action is otherwise similar.

Obviously, the invention may be employed with other types of cables than the one illustrated. It will be understood that the term "coaxial" as herein used extends to any construction in which the inner conductor (of which there may of course be more than one) is enclosed within an outer conductor, the invention obviously not being limited to the central relation shown. It will also be observed by those skilled in the art that the particular embodiments shown are in many other respects merely illustrative. Accordingly, the scope of the patent protection to be afforded the invention should be determined in terms of the definitions set forth in the appened claims, and equivalents thereof.

What is claimed is:

1. In a coaxial cable comprising at least one inner conductor, a foam plastic dielectric enclosing the inner conductor, and a generally tubular outer conductor enclosing the sleeve and having an internal groove extending at least partially in the longitudinal direction, the crest of the internal groove being spaced from the dielectric to form a continuous passage extending along the cable, the improved construction characterized by water-sealing barriers filling the passage only at closely spaced intervals along the length of the cable, so that the effect of a water leak is greatly reduced with a volume of barrier material substantially less than the volume of the groove.

2. The cable of claim **1** having the viscous solid distributed at spaced intervals in the passage and having means for blocking substantial exit of water between the roots of the corrugations and the outer surface of the dielectric, so that water entering any portion of the passage is confined in that portion.

3. In a coaxial cable comprising at least one inner conductor, a continuous flexible plastic dielectric en-

closing the inner conductor, and an outer conductor surrounding the dielectric, the outer conductor being helically corrugated and the crests of the corrugations being spaced from the dielectric to form a helical passage, the improved construction characterized by having means for blocking direct longitudinal flow at the roots of the corrugations and a sealant material blocking the passage only at spaced intervals to confine water to the portion of the passage within the interval at which any leak occurs.

4. The cable of claim 3 having the sealant material in a portion of every turn of the helical passage, so that the length of the surface of the dielectric exposed to water entering through any leak is limited substantially to the pitch of the helix.

5. The cable of claim 4 having the sealant material in the corresponding circumferential positions in all turns, to form at least one straight longitudinal line of barriers.

6. The cable of claim 4 having the sealant material in successive turns at circumferential positions forming at least one continuous line of barriers.

7. The cable of claim 6 having a viscous solid as the sealant material.

8. In a high-frequency transmission element which includes an elongated body of foam plastic dielectric contained in a helically corrugated sheath, the dielectric being exposed to water entering the sheath, the improvement comprising a barrier material blocking the interior of the corrugations only at spaced intervals along the helical path thereof, so that the length of the dielectric exposed to water entering through a leak is limited to the corresponding interval.

9. The high-frequency transmission element of claim 8 wherein the barrier material is a viscous solid.

10. In a method of making coaxial cable the steps of:

(a) forming an assembly of at least one inner conductor embedded in an insulator sleeve within a tubular outer conductor of greater inner dimension than the outer dimension of the insulator, with a longitudinal strip of barrier material more yielding than the insulator in only a circumferential portion of the space between the insulator and the outer conductor and

(b) helically corrugating the outer conductor and forming a water enclosure at the roots of the corrugations, the barrier material thus blocking each turn of the substantially sealed helical passage formed in the crests of the corrugations while leaving voids in the circumferential intervals thus formed.

11. The method of claim 10 wherein the barrier material is a viscous solid.

12. The method of making long continuous lengths of coaxial cable comprising the steps of:

(a) forming an assembly of at least one inner conductor with a surrounding tubular insulator,

(b) continuously forming a conductor strip to tubular shape around said assembly while enclosing in every substantial longitudinal portion a barrier material more readily deformable than the insulator, the tubular shape being larger than the insulator and the barrier material filling only a circumferential portion of the space therebetween in each such longitudinal portion,

(c) sealing the seam formed by the edges of the conductor strip to complete the formation of the outer conductor and

(d) helically corrugating the outer conductor and forming a water seal at the roots of the corrugations, the barrier material being deformed by the corrugations and blocking turns of the substantially sealed helical passage thus formed in the crest of the corrugations while leaving voids in the circumferential intervals between the regions of such blocking.

13. The method of claim 12 wherein the barrier material is enclosed as a continuous longitudinal strip in a circumferential portion substantially spaced from the seam, and the seam is sealed by welding.

14. The method of claim 13 wherein the barrier material is a viscous solid.

15. The method of claim 13 wherein the barrier material is deposited on the conductor strip at a point substantially removed from the edge thereof and is supported thereby as the enclosure is completed.

16. In the method of manufacture of a flexible electrical transmission element which comprises

(a) continuously feeding an elongated conductor strip and an elongated dielectric through a processing region,

(b) continuously forming the conductor strip to the shape of a tube surrounding the dielectric but of larger size than the dielectric in a first portion of the processing region,

(c) continuously sealing the seam of the tube thus formed in a second portion of the processing region, and

(d) continuously helically corrugating the tube in a third portion of the processing region to form a transmission element having a helical internal passage,

the improvement comprising

(e) continuously dispensing a flowable sealant material on only a portion of the surface of at least one of said elongated elements, and

(f) continuously enclosing the sealant material so dispensed with the dielectric in said first portion,

(g) the volume of sealant material so enclosed with any length of the dielectric being substantially less than the volume of the corresponding passage thereafter formed along such length but sufficient to block the passage against flow of water.

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LARAMIE E. ASKIN, *Primary Examiner.*

A. T. GRIMLEY, *Assistant Examiner.*