United States Patent

[11] 3,576,939

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[54] **ELECTRICAL CABLES AND METHOD OF MAKING SAME**
10 Claims, 13 Drawing Figs.

[52] **U.S. Cl.** **174/107,** 156/54, 174/36, 174/110
[51] **Int. Cl.** **H01b 7/18**
[50] **Field of Search** .... 174/36, 102—110, 113; 156/54—56

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ABSTRACT: Electrical cables having an outer shielding element of thin metal tape; the tape being shaped into tubular form about the cable core and having a longitudinal seam; the seam having marginal tab portions integral with the tape and in face-to-face contact, the outer edges of the tab portions being metallically integrated to provide electrical conductivity continuously about the circumference thereof and to form a fluid-impervious envelope for the core which is resistant to mechanical stresses.

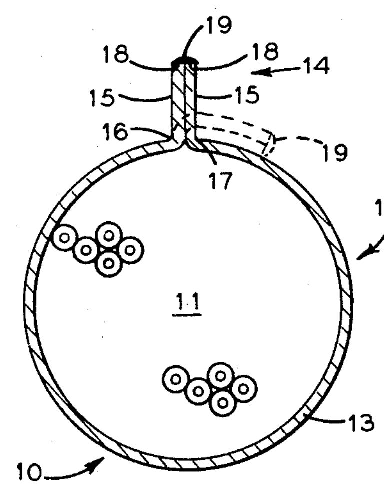


FIG. 1

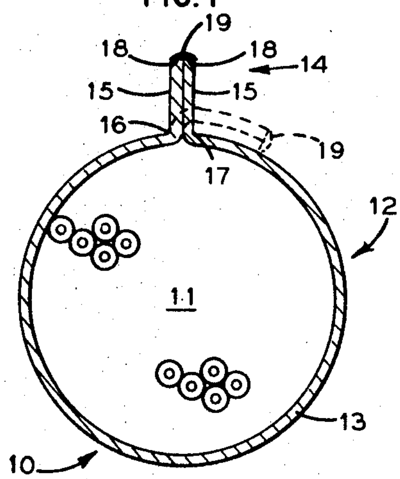


FIG. 2

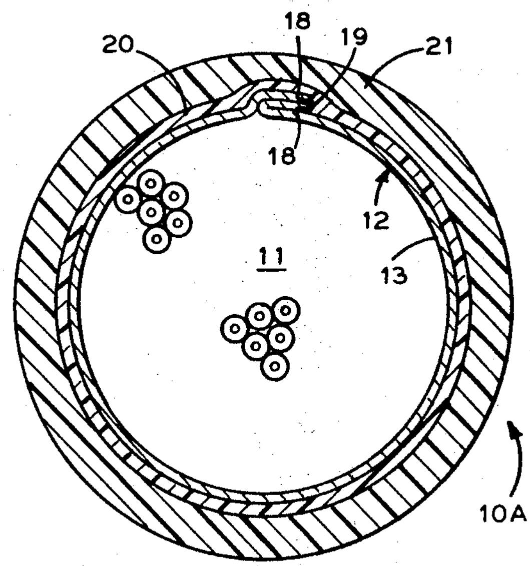


FIG. 3

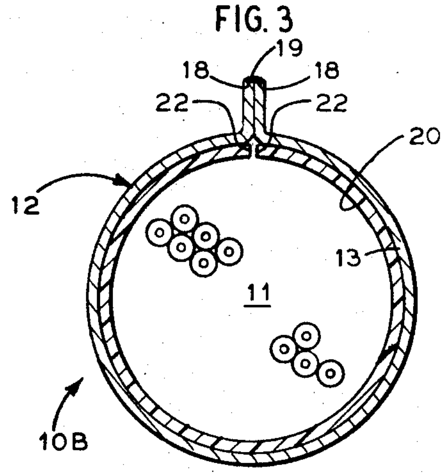
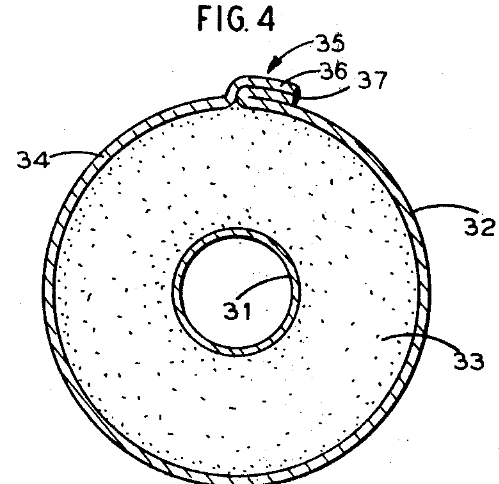


FIG. 4



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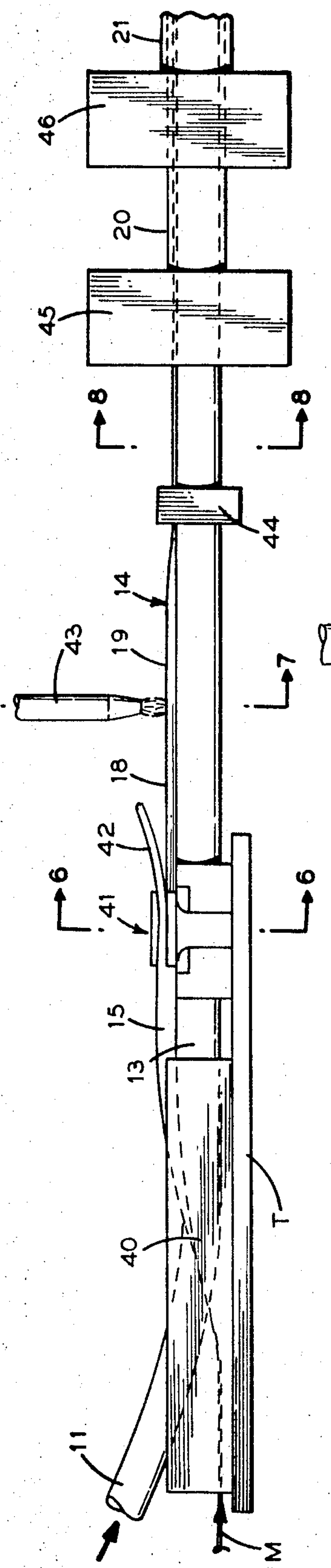


FIG. 5

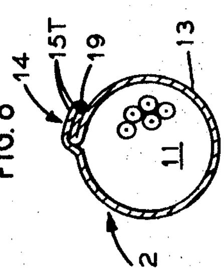


FIG. 8

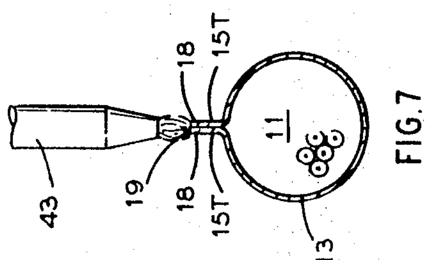


FIG. 7

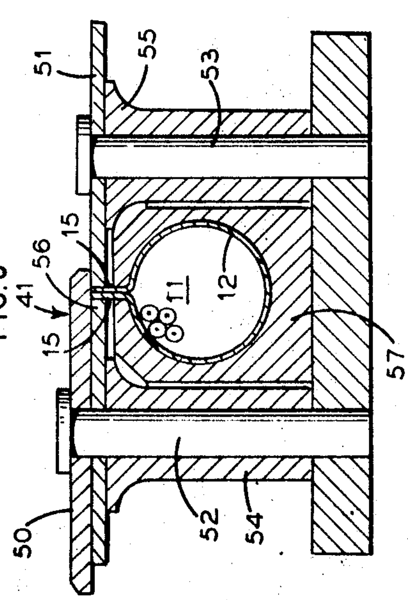


FIG. 6

FIG. 9

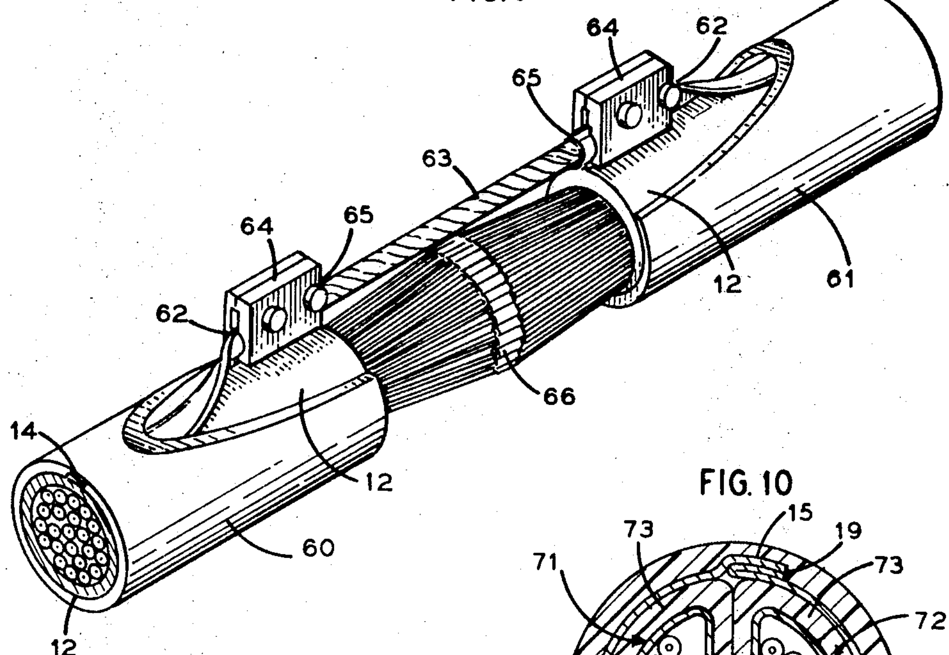


FIG. 10

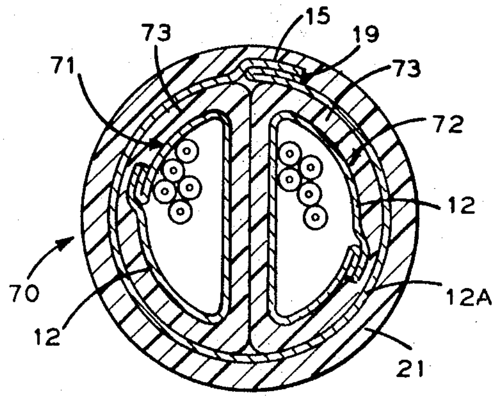


FIG. 11

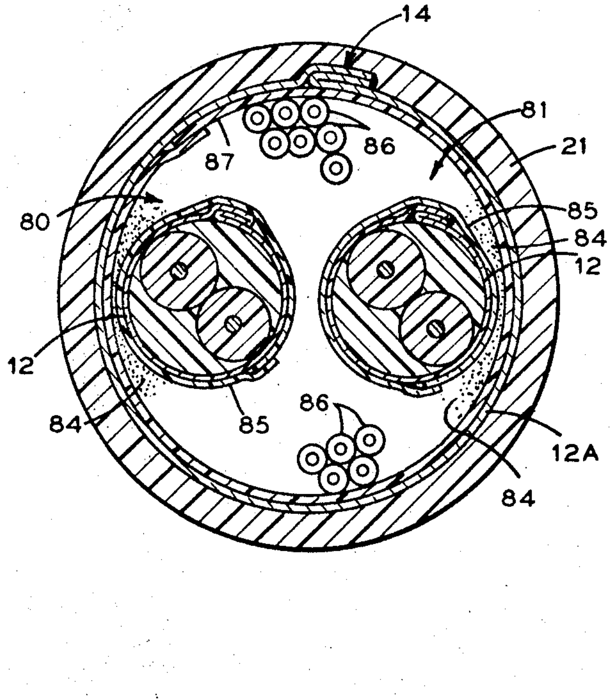


FIG. 12

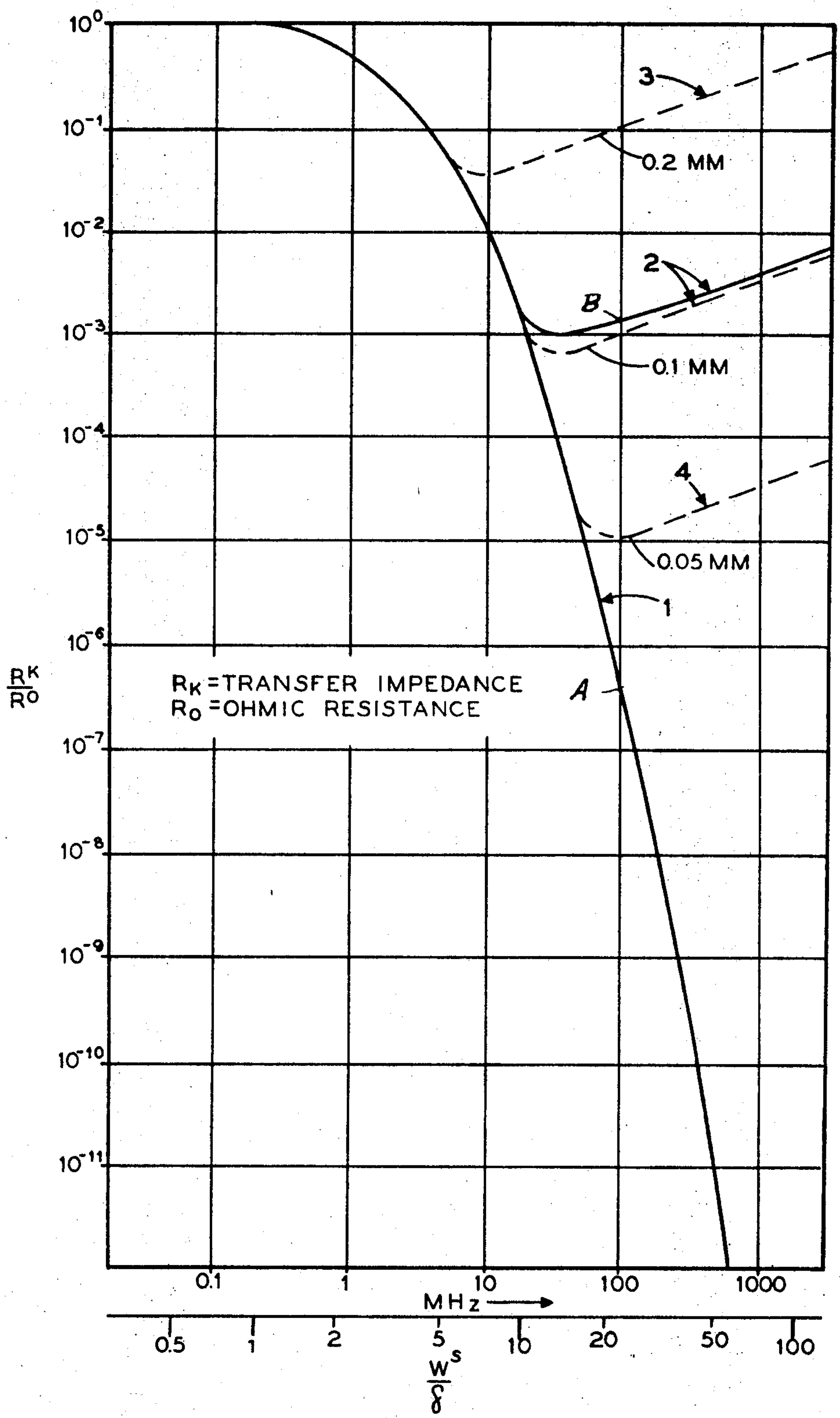
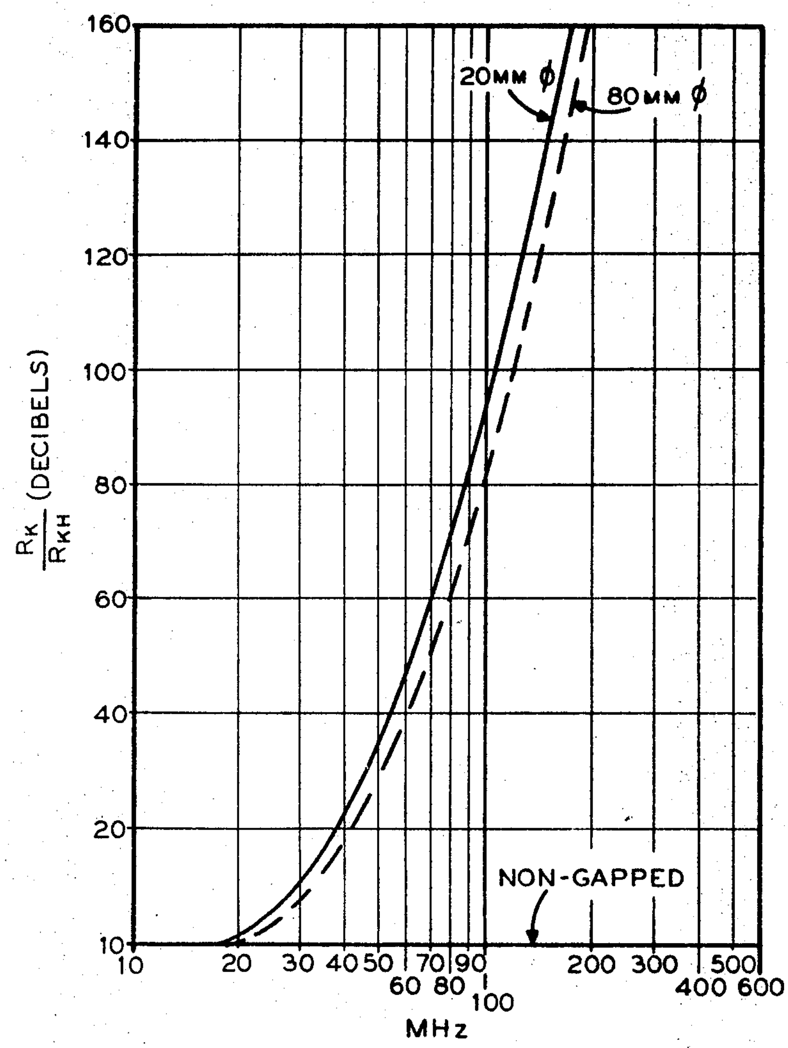

10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^{-11}
$\frac{R^K}{R^O}$
3
0.2 MM
2
B
0.1 MM
4
0.05 MM
1
A
R_K =TRANSFER IMPEDANCE
R_O =OHMIC RESISTANCE
0.1
1
10
100
1000
MHz
0.5
1
2
5
10
20
50
100
$\frac{W^s}{\delta}$

FIG. 13


160
140
120
100
80
60
40
20
10
$\frac{R_K}{R_{KH}}$ (DECIBELS)
20MM ϕ
80MM ϕ
NON-GAPPED
10
20
30
40
50
60
70
80
90
100
200
300
400
500
600
MHz

ELECTRICAL CABLES AND METHOD OF MAKING SAME

BACKGROUND OF THE INVENTION

The increasing trend toward locating communications cables in the ground has made it necessary to provide means for protecting the buried cable from the ingress of moisture. This can be accomplished by enclosing the cable core in an impervious metal envelope or by filling the cable core with a waterproof flooding compound; or a combination of such procedures.

The metallic envelope, in addition to serving as a moisture barrier, must also provide the required electrical conductivity to allow the same to function as a shielding means.

The instant invention is concerned with a thin metal sheath or covering for a cable core, preferably of aluminum, which combined vapor imperviousness, corrosion resistance, good shielding characteristics and mechanical properties facilitating the flexing and reeling of the cable.

A number of sheath designs have been proposed which purport to satisfy the aforementioned requirements. Thus, in one case, it is proposed to use aluminum tapes coated with monomer modified polyethylene resin which is highly adherent to the metal. The tapes are longitudinally folded about the cable core with the edges overlapped and heat sealed. Usually, inner and outer jackets of polyethylene resin are fused to the coated tape.

In another case, a double sheath construction is proposed, wherein the inner sheath consists of aluminum tape of at least 0.001 inch thickness and coated on opposite sides with polyolefin resin. The sheath-forming tape is loosely folded about the cable core and the marginal edges of the tape are bent to form radially extending tabs which are heat sealed through the intervening resin coatings. The projecting sealed tabs are then folded over against the sheath and an outer sheath is then applied. The outer sheath constructions are known in the art under the designations of Alpeth, Stalpeth or FPA.

The instant invention constitutes a further development of known thin-walled metal envelopes for cables wherein a metal tape is formed in tubular shape about the cable core, the edges of the tape being brought into abutting relation, and welded together. The resultant envelope is then drawn down or transversely corrugated to provide a tight fit between the sheath and the cable core.

However, it has been found that with metal tapes having a thickness of 0.010 inch or less, the forming and butt-welding operations present difficulties, particularly in the case of larger core diameters. This is due to a lack of form stability of the thin metal tape and variations in metal thickness in commercially available tapes.

It has also been proposed to provide metal sheathing by welding overlapped edge portions of the thin metal tape folded about a cable core. This method is reasonably applicable to copper tapes but cannot be easily used with aluminum tapes due to the presence of oxide layers on the overlapped tape surfaces. Such oxide layers make it exceeding difficult to obtain a sound, uniform metallic bond therebetween.

Accordingly, an object of this invention is to provide an improved sheath or covering in electrical cables which overcomes the disadvantages of known constructions. More particularly such sheath provides a thin-walled metal envelope for the cable core wherein the envelope includes a longitudinal seam comprising facing, radial tab portions which are metallically integrated to make the seam impermeable to fluids; highly resistant to mechanical stresses under severe conditions of handling and installation; and further, to provide continuous circumferential electrical conductivity to significantly enhance the shielding characteristics of the cable.

A further object of this invention is to provide a cable sheath which is formed of very thin metal tapes, including aluminum tapes, wherein the tape is folded about the cable core to accommodate any irregularities in the surface portions of the core; the tape having sufficient width in relation to the circumference of the core, to provide marginal tab portions which are brought into face-to-face contact; the outer edges of the tab portions being trimmed to leave the tab portions at a predetermined height, with such edges coextensive and presenting freshly cut, oxide-free edge surfaces which are immediately thereafter welded or otherwise metallically integrated.

Another object of this invention is to provide a thin metal sheath or covering of the character described, wherein the outer surface of such sheath has applied thereto a metal adherent synthetic resin which renders the sheath corrosion proof, together with a protective jacket of synthetic resin applied over the metal adherent resin and bonded thereto.

Yet a further object of this invention to provide a sheath or covering for electrical cables of the character described, wherein such sheath or covering may be formed of exceedingly thin metal tapes which minimizes metal requirement; which may be stiffened by the resin coatings applied thereto to resist mechanical stresses; and which shows excellent shielding characteristics.

Still another object of this invention is to provide improved cable constructions of the character described, wherein the sheath or covering is formed of metal tape folded about the cable core to provide tab portions in face-to-face relation and initially radially disposed for metallic integration of their edges; the metal tape having minimal thickness which permits the cable, after folding the tab portions downwardly against the sheath, to be readily flexed, reeled and unreeled.

Yet another object of this invention is to provide cable constructions of the character described and having a sheath showing enhanced shielding characteristics, making the same particularly useful in communications cables where interference exteriorly and interiorly thereof must be eliminated or minimized.

Yet a further object of this invention is to provide improved electrical cables of the character described, wherein the tab seam portions thereof may be folded or otherwise manipulated to facilitate cable-splicing operations, cable suspension and to provide a variety of cable configurations.

Still another object of this invention is to provide improved methods of forming electrical cables having a thin metal sheath with a longitudinal seam having radial tab portions with oxide-free edges metallically integrated to provide continuous electrical conductivity circumferentially of the sheath.

Other objects of this invention will in part be obvious and in part hereinafter pointed out.

DESCRIPTION OF THE DRAWINGS

FIG. **1** is a transverse sectional view showing an electrical cable having a sheath or covering embodying the invention;

FIG. **2** is a view similar to that of FIG. **1**, showing another embodiment of the invention;

FIG. **3** is a view similar to that of FIG. **1**, showing a further embodiment of the invention;

FIG. **4** is a view similar to that of FIG. **1**, showing still another embodiment of the invention;

FIG. **5** is a side elevational view schematically showing apparatus for forming cable of the instant invention;

FIG. **6** is a transverse sectional view taken on the line **6–6** of FIG. **5**;

FIG. **7** is a sectional view taken on the line **7–7** of FIG. **5**;

FIG. **8** is a sectional view taken on the line **8–8** of FIG. **5**;

FIG. **9** is a perspective view showing a splice construction for cables embodying the invention;

FIG. **10** is a transverse sectional view showing a twin unit cable embodying the invention with shielding between the units thereof;

FIG. **11** is a transverse sectional view of a video cable embodying the invention;

FIG. **12** is a graph showing the shielding characteristics of cables having known gapped-type shields and continuous shields of the instant invention; and

FIG. 13 is a graph further illustrating comparative shielding characteristics of cables having gapped and continuous shields.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The instant invention is concerned with electrical cables embodying tubular sheaths or coverings of thin metal tape for the cable core or cores thereof to exclude the entry of harmful liquids, vapors or gases therein; the sheath or covering being highly resistant to mechanical stresses and showing excellent shielding characteristics.

The coverings are formed from metal tapes having a wall thickness not exceeding about 0.30 mm.; the metal being preferably aluminum; although copper, steel or other metals and alloys thereof, may also be used.

Thus, as shown in FIG. 1, 10 designates an electrical cable having a conventional core 11 made up of the usual insulated conductors. The core 11 is enclosed in an envelope 12 formed from a metal strip 13 which is folded about core 11.

Strip 13, of aluminum, has a width greater than the circumference of core 11, so as to provide a longitudinal seam portion 14 comprising marginal portions 15 of the strip 13 which are bent from edge portions 16, 17 to dispose portions 15 in radially extending, tab form, said portions 15 being in face-to-face contact.

The tab edges 18 are coextensive throughout their length, such edges being trimmed by cutting to a predetermined tab height. The resultant oxide-free edges 18 are metallically integrated by a continuous, longitudinal weldment 19 bridging said edges.

The upstanding tab seam 14 may be folded over at edges 16, 17 to dispose the same against the outer surface of envelope 12, as indicated in the dotted lines. Thus, the cable 10 may be readily flexed for reeling, unreeling and installation.

As shown in FIG. 2, the cable 10A, is similar to cable 10, except that a coating 20 of synthetic resin highly adherent to metal is applied to the outer surface of envelope 12, as by extrusion, coating, electrophoretic deposition and the like. Such resin may be formed of copolymers of polyethylene and selected monomers, as described in U.S. Pat. Nos. 2,987,501 and 3,027,346. Coating 20 renders the envelope 12 highly resistant to corrosion and imparts some stiffness to the thin metal of the envelope.

A jacketing coating 21 is applied over coating 20 by extrusion or the like; coating 21 being of polyethylene, polyvinyl chloride, or the like. Coating 21 will adhere to coating 20, and will provide adequate protection to the cable 10A.

A cable 10B, as shown in FIG. 3, is similar to cable 10, shown in FIG. 1, except that the metal strip 13 is precoated with metal adherent synthetic resin coating 20A, similar to coating 20, previously described. Coating 20A is applied to metal strip 13 to dispose the same on the inner surface thereof, the marginal edges 22 of the coating being spaced from edges 18 of the strip, to locate coating edges 22 adjacent or abutting each other. Also, coating 20A may be applied to the outer surface of strip 13, or to both surfaces thereof; such coating or coatings serving to render the envelope 12 resistant to corrosion.

Further, as shown in FIG. 4, the coaxial cable 30 comprises the usual inner conductor 31 which may be in tubular form and an outer conductor 32 held in concentric relation to inner conductor 31 by an intervening annular body 33 of synthetic resin foam, or other suitable dielectric spacing means.

Outer conductor 32 is formed of metal tape 34 bent into tubular shape with a seam portion 35 made up of tab portions 36 metallically integrated as at 37, in the manner previously described. The tab seam 35 is bent over against the outer surface of the outer conductor 32. Metal adherent and jacketing resin coatings may be applied to cable 30, as previously described.

FIGS. 5 to 8 show an apparatus and method for making cable 10. The same comprises a forming table T along which cable core 11 taken from a reel thereof, not shown, moves longitudinally, together a metal tape M taken from a reel thereof, not shown, to a tube-forming device 40, well known in the art and which folds the same into tubular form 13 about core 11 to form envelope 12.

The tape M has a width greater than the circumference of cable core 11, so that the marginal portions thereof form the upstanding, radially disposed tab portions 15 in face-to-face relation. The assembly of cable core 11 and covering 13 move along table T to a trimming device generally indicated at 41, where the tab portions 15 are cut to a determined tab height, bringing freshly cut edges 18 thereof in a true alignment.

The assembly continues its movement past trimming device 41, the trimmed portion 42 of tab portions 15, being suitably removed; and bringing the fresh-cut edges 18 thereof into precise, measured alignment with suitable welding means 43, preferably operating under a protective atmosphere of argon or the like, whereby to weld and metallically integrate tab edges 18 by way of continuous weldment 19 bridging said edges. The welding rate may be from 5 to about 24 meters per minute with welding currents ranging from about 12 to about 70 amperes.

The resultant tab seam 14, which may have a height of from about 4.0 mm. to about 8.0 mm. is folded over from its radial position by means of a suitable folding die 44. The coating 20 of metal adherent resin is applied by means of an extruder 45 while jacketing coating 21 is applied over coating 20 and in bonding relation thereto, by an extruder 46 or other suitable applying means.

The trimming means as shown in FIG. 6, comprises a pair of horizontally disposed cutter discs 50, 51 mounted for rotation by way of vertical shafts 52, 53 disposed in bearing means 54, 55 and driven by suitable means, not shown. A guide disc 56 is mounted on shaft 52 below cutter disc 50, with its peripheral edge slightly spaced from horizontally aligned cutter disc 51 to thereby position tab portions 15.

Guide means 57 of molded plastic or the like, passes the assembly of cable core 11 and envelope 12 to the cutter disc 50, 51. Thus, the tab portions 15 are properly aligned for presentation to welding means 43. In the completed cable assembly, FIG. 8, the downturned tab portions 15T of seam 14 lend themselves to further manipulation for electrical interconnection or termination of the envelopes 12 at the cable ends which are to be spliced or terminated.

Thus, as shown in FIG. 9, cables 60, 61 having thin metal envelopes 12 are suitably spliced in respect to both the cable cores and the envelopes thereof. Short, terminal sections 62 of seam 14 are raised to their original radial positions and interconnected by a ground wire 63, which are secured in place by connecting blocks 64; the cable cores of cables 60, 61 being connected and spliced in the usual manner, as at 66.

Excellent electrical connection is made between ground wire 63 and envelopes 12, by inserting a suitable tool, not shown between the tab portions of terminal sections 62 to form recesses 65. The ends of wire 63 are inserted into said recesses 65 and the connecting blocks 64 are then applied to clamp and compress the inner surfaces of the opposed tab portions against the ends of wire 63 to complete the electrical connection between the envelopes of cables 60, 61.

Envelopes of the type previously described are particularly effective to eliminate or minimize interference which might otherwise arise due to proximity between pairs in communications cables. Thus, as shown in FIG. 10, a cable 70 suitable for carrying both transmission directions of PCM signals comprises a pair of cable units 71, 72 in side-by-side relation. Each unit 71, 72 is enclosed in an envelope 12, formed as previously described. A layer of insulation 73, such as resin or tape is applied about units 71, 72, followed by an outer sheath construction constituted of a metal envelope 12A, formed as previously described and a jacketing layer 21 of polyethylene, polyvinyl chloride or the like, applied over the envelope by extrusion of the like.

The cable 70 may further include synthetic resin coatings applied directly to the outer surface of the envelope 12A to which the jacket coating **21** is applied and bonded. Excellent go and return transmission paths, effectively shielded relative to each other, is provided by this construction.

As shown in FIG. **11**, a video cable is made up of video pairs **80, 81** which are respectively enclosed in envelopes **12** and aggregated in a suitable dielectric filler **84**; the pairs being enclosed in core tapes **85**. An outer shield **12A**, formed as previously described, together with a jacket coating **21** encloses the video units **80, 81**. Other insulated pairs or conductors **86** may be included in the unitary cable construction.

Such a cable construction effectively eliminates interference between the video pairs **80, 81**, as well as between the video pairs and other pairs or conductors **86** included in the cable.

The shielding characteristics of the envelopes **12, 12A** and **32**, as hereinbefore described, are enhanced, particularly as compared to known shield constructions having a longitudinal electrical gap which causes circumferential electrical discontinuity in the shield.

Thus, as indicated in FIG. **12**, the graph shown therein, sets forth the relationship between the ratio of transfer impedance R_k to ohmic resistance R_o, indicative of shielding effectiveness, and frequency of interfering signals in mHz, for electrical cables having shields made in accordance with the instant invention, as compared to shields of the circumferentially discontinuous, gapped type. Such known shield constructions include resin-coated tapes of metal which are disposed about the cable core with overlapped or facing longitudinal seam portions with resin between the metal seam portions, giving the indicated circumferential electrical discontinuity or gap.

In FIG. **12**, the characteristics of cables having a diameter of 20 mm., with aluminum shields having a wall thickness of 0.2 mm.; one cable having a continuous shield in accordance with the instant invention; the other cables having shields of the gapped type, are set forth. The induced voltage on the surface of the shield was obtained in terms of the transfer impedance of the system.

It is evident that the ratio of transfer impedance to ohmic resistance with shields of the instant invention, decreases rapidly and exponentially with increase in frequency of the interfering signals, as indicated by the solid line; whereas, for those shields of the gapped type and lacking circumferential electrical continuity, beyond a certain frequency, the ratio reverses its tendency to decrease in value at lower frequencies and commences to increase in value, as set forth in the dash lines, indicating a marked fall-off in shielding effectiveness. Such fall-off continues at an increasingly accelerated rate with increase in frequency beyond the critical point.

This is particularly noted where at 100 MHz., the shielding effect indicated on the curve **1** at point A for the shield of the instant invention, is more effective by a factor of at least 10^3 as compared to point B on curve **2** for a gapped-type shield where the gap width is 0.1 mm. The shielding performance for gapped-type shields where the gap width is 0.2 mm. and 0.05 mm. is indicated by curves **3, 4** respectively in FIG. **12**.

In FIG. **13** there is shown an alternative method of demonstrating comparative shielding performance for gapped, and nongapped shields of the instant invention. Here the ratio of transfer impedance of a gapped shield R_k to transfer impedance of a nongapped shield R_{kh} is plotted against the frequency of interfering signals.

Thus, the values of the ratio R_k/R_{kh} expressed in decibels are plotted for shields having diameters of 20 mm. and 80 mm., both having a gap of 0.1 mm. At 100 MHz., the shielding effectiveness of a 0.1 mm. gapped shield of 20 mm. diameter, is reduced by a factor of 90 decibels in comparison to a shield of the same diameter and wall thickness, having no gap and being circumferentially electrically continuous, as in the instant invention.

The shielding effectiveness of a metallically integrated envelope or tube can be calculated by known formulas. At higher frequencies the shielding effect is related to wall thickness of the envelope and depth of penetration of currents in the material; whereas in a gapped envelope, the shielding effectiveness depends on:

cable diameter D

shield wall thickness s

gap width b

depth of penetration δ,

which in turn depends on the specific resistivity of the metal and on frequency.

Essentially, the ratio of the transfer impedance of a shield with a gap, R_k, to that of a shield without a gap, R_{kh}, may be expressed by the formula:

$$\frac{R_k}{R_{kh}} \simeq 1 + 0.53 \cdot \frac{2s}{D} \cdot \left(\frac{b}{s}\right)^2 \cdot e^{-\pi\frac{s}{b}} \cdot e^{+\frac{s}{b}}$$

I claim:

1. An electrical cable comprising a cable core and a tubular member enclosing said core, said member being formed of metal having a wall thickness not exceeding about 0.30 mm. and having a longitudinal seam portion, said seam portion comprising a pair of radially extending tab portions integral with said member, and means for metallically integrating said tab portions at the outer edges thereof to thereby provide a fluid-impervious envelope for said core and continuous electrical conductivity circumferentially thereof.

2. A cable as in claim **1** wherein said member is formed of aluminum and the outer edges of said tab portions being oxide free; said oxide-free edges being metallically integrated.

3. A cable as in claim **2** wherein a weldment bridges and connects the outer edges of said tab portions.

4. A cable as in claim **1** and further including a coating of metal adherent synthetic resin on the outer surface of said tubular member.

5. A cable as in claim **4** and further including a jacketing of synthetic resin over said coating of metal adherent resin and bonded thereto.

6. A cable as in claim **1** wherein said tab portions are folded along the base thereof into contact with an outer surface portion of said member.

7. A cable as in claim **6** wherein terminal portions of said folded down tab portions at the terminal end of the cable are refolded to a radial position thereof to provide connector means for electrically interconnecting the terminal end portions of said tab portions of a pair of said cables.

8. A cable as in claim **7** wherein the terminal portions of said tab portions have facing portions thereof displaced from each other to form a longitudinal recess, and wire means having the terminal ends thereof inserted into the recesses of a pair of said cables, and means for clamping each of the terminal portions of said tab portions to retain the wire ends in said recesses.

9. A cable as in claim **1** wherein said cable core comprises a pair of adjacent core elements, each core element being enclosed in a metal envelope, said envelope comprising a tubular envelope having a wall thickness not exceeding about 0.30 mm. and a fluid impervious longitudinal seam therein, said seam comprising longitudinally extending tab portions in facing contact, the edges of said tab portions being metallically integrated.

10. A coaxial cable comprising an inner conductor and an outer conductor, and dielectric means for maintaining said conductors in spaced concentric relation to each other, said outer conductor comprising a tubular metal member having a wall thickness not exceeding about 0.30 mm. and a longitudinal fluid-impervious seam therein resistant to mechanical stresses, said seam comprising a pair of tab portions integral with said member in facing relation to each other and means for metallically integrating the outer edges of said tab portions.