May 20, 1969 A. T. EDWARDS ET AL 3,445,586

LOOSE-CORE CONDUCTOR HAVING IMPROVED SELF-DAMPING COMBINED WITH IMPROVED INTERNAL WEAR RESISTANCE

Filed Dec. 30, 1966 Sheet 1 of 2

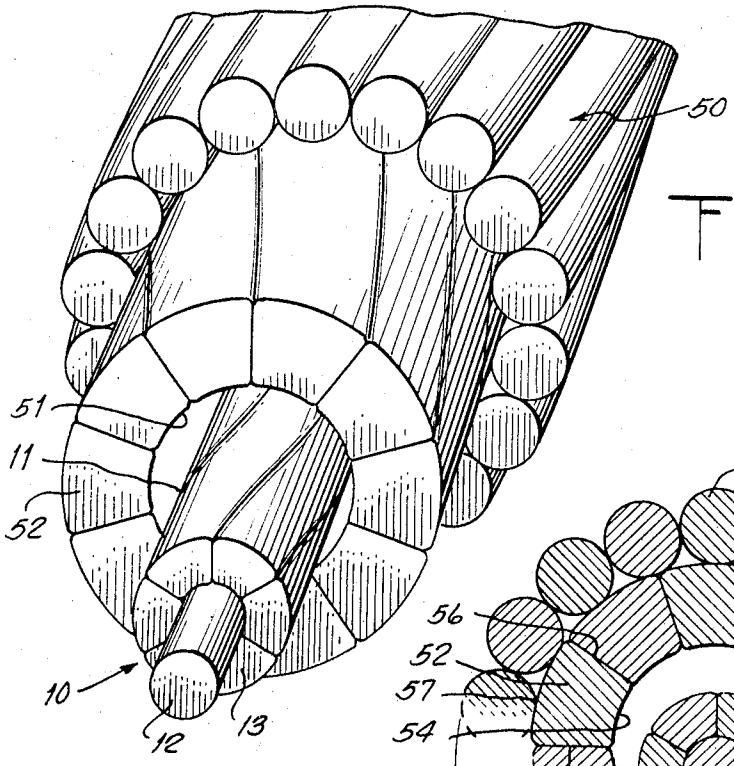


Fig. 1.

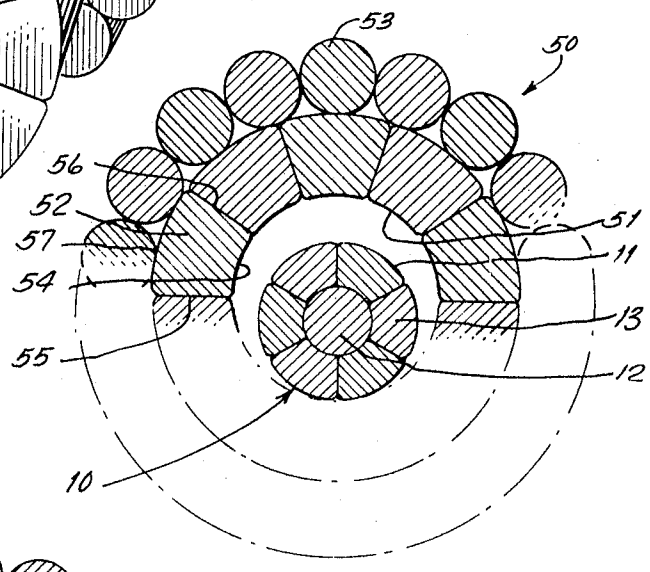


Fig. 2.

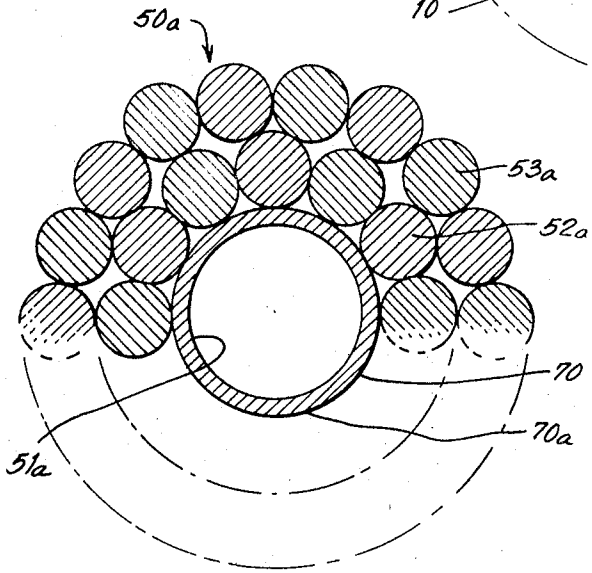


Fig. 3.

AUBREY THOMAS EDWARDS
GUY AUBREY MUSSEN
INVENTORS

BY

Robert S. Dunham
ATTORNEY

May 20, 1969 A. T. EDWARDS ET AL 3,445,586
LOOSE-CORE CONDUCTOR HAVING IMPROVED SELF-DAMPING COMBINED WITH IMPROVED INTERNAL WEAR RESISTANCE
Filed Dec. 30, 1966 Sheet 2 of 2

Fig. 4.

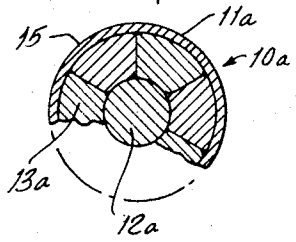


Fig. 5.

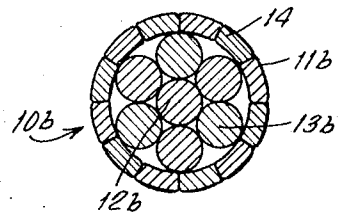


Fig. 6.

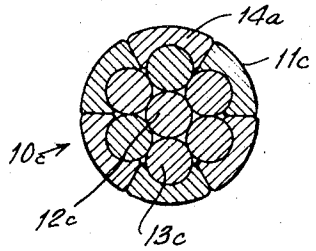


Fig. 7.

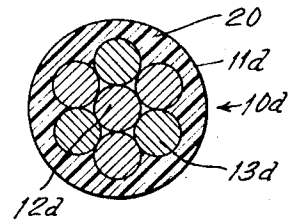


Fig. 8.

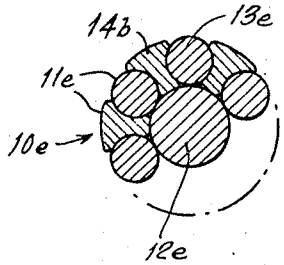
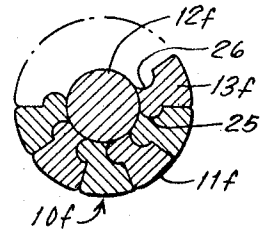


Fig. 9.



AUBREY THOMAS EDWARDS
GUY AUBREY MUSSEN
INVENTORS

BY
Robert S. Dunham
ATTORNEY

United States Patent Office 3,445,586
Patented May 20, 1969

3,445,586

LOOSE-CORE CONDUCTOR HAVING IMPROVED SELF-DAMPING COMBINED WITH IMPROVED INTERNAL WEAR RESISTANCE

Aubrey T. Edwards, Oakville, Ontario, and Guy A. Mussen, Westmount, Quebec, Canada, assignors to Aluminium Laboratories Limited, Montreal, Quebec, Canada, a corporation of Canada

Filed Dec. 30, 1966, Ser. No. 606,338
Int. Cl. H01b 5/10; H02g 7/14
U.S. Cl. 174—130 4 Claims

ABSTRACT OF THE DISCLOSURE

A cable for use in overhead transmission lines, of the type having a multi-stranded core including steel wires to bear the preponderance of the tensile forces acting upon the cable, and a sheath surrounding the core and spaced radially therefrom, so that the core is loose within the sheath, the sheath comprising multiple strands of a good electric conductor which is softer than steel, e.g. aluminum, the improvement comprising providing the core with an outer layer of conductor material substantially as soft as the conductor material in the sheath, and having a smooth outer surface, and providing the inner surface of the sheath with a smooth surface, the smooth inner surface of the sheath and the smooth outer surface of the core being spaced apart at least 50 mils in difference of diameter. In the preferred embodiment the inner layer of sheath wires are aluminum, and have surfaces which mutually cooperate to define the aforesaid smooth inner sheath surfaces; and the core comprises a steel wire or wires surrounded by a plurality of aluminum wires also having cooperating surfaces defining the aforesaid smooth outer surface of the core. A highly advantageous geometric configuration for aluminum wires useful to form either of these two cooperative smooth surfaces is that of a truncated segment, as defined and illustrated herein. It is alternatively convenient to compact aluminum wires upon the steel wire or wires to form the core, as by drawing the assembly through a die.

By use herein of the term wire, is meant an elongated single strand of metal. These individual wires are stranded into cables for transmission of electrical energy. In this specification, such stranded wire cables will be described as conductors and the wires are thus conductor wires, although depending upon frequency and voltage, not all the wires in a cable will necessarily carry the same amount of current. Indeed, some wires are specifically intended to serve almost exclusively as tension or load-bearing members, while others serve almost exclusively as electricity conducting members. Nevertheless, all are conductors since they are capable of conducting electricity and in fact do all conduct some quantity under normal service conditions.

Transmission line conductors are prone to serious vibration problems. These vibration problems arise in two ways. When subjected to relatively low velocity winds, i.e. in the range 1–20 m.p.h., "aeolian vibration" occurs. Aeolian vibrations are of relatively low peak-to-peak amplitude (e.g. up to about the conductor diameter), and relatively high frequency (e.g. 2 to 200 cycles per second). When subjected to higher velocity winds, e.g. 15 to 30 miles per hour, and when certain other conditions such as icing of the conductors are present, a transmission line is sometimes subject to "galloping," that is to say, to vibrations having an amplitude ranging from a few inches to 20 or even 30 feet, and a frequency in the order of 0.25 cycle per second.

The present invention is concerned with damping these kinds of vibrations in multiple-wire conductors, so that the well known destructive tendencies of such vibrations are avoided, i.e. weakening of the supports for the line, fatigue of the conductor metal, overloading of the conductors, and the like.

It is known in the art to damp these vibrations by presenting an inner core of wires and an outer sheath of wires, the outer sheath being concentric with but spaced from the inner core of wires, so that the two groups of wires strike one another during the displacement caused by the vibrations, thereby damping the vibrations by interference, and by absorbing and exchanging the vibration energy in the impacting and rubbing between the inner and outer elements. In the usual construction, the core wires include strong structural wires, such as steel, to bear the mechanical load, while the sheath wires are fabricated in a high conductivity metal, not necessarily as strong structurally, such as aluminum alloys designed for that purpose. Although at transmission line voltages the current may be carried principally, or even virtually entirely, by the outer sheath of wires, all wires of the cable are conveniently referred to herein as conductor wires, whether in the sheath or core. In the past, all such constructions have, while damping transmission line vibrations, introduced wear. The inner steel core wires are generally coated with zinc or another protective material, while the outer wires are generally fabricated in a softer, highly conductive metal such as aluminum, as aforesaid. Adjacent layers of two groups of wires are generally stranded in opposite directions, for maximum torsional strength and stability, and thus, if so stranded with round wires in opposite directions, when the two groups touch, it is at point contacts, thereby introducing very high unit loadings at the contacting points between the round wires. However, some adjacent layers of the two groups of wires may also be stranded in the same direction, and if so, and if two such groups touch, they still do so at point contacts, because while the pitch of the two layers may be the same, coincidence of the wires is remote, so that high unit loadings are still introduced at the contacting portions.

Under vibration, the inner and outer groups of wires clash, as they are intended to do, but because of the aforesaid point or line contacts, the protective coating on the steel core wires wears away, and the aluminum or other softer metal outer wires also become worn. If the coating is worn away on the steel core wires, they become subject to corrosive attack, and if the aluminum outer wires are scored or otherwise worn, they may be seriously reduced in strength. These results are very undesirable from the service standpoint, and are scarcely exceeded in undesirability by the vibration-induced problems themselves.

The principle of the invention is the reduction of high unit loading at areas of impact between the inner core and the sheath thereby reducing wear and deformation of metal.

It is an object of the present invention to provide a multiple-wire conductor construction useful for overhead transmission lines and combining efficient damping of vibrations with markedly reduced conductor wear due to clashing and rubbing of conductor wires.

Another object of the invention is to provide such a conductor construction which is capable of superior service under various overhead transmission line service conditions.

Another object of the invention is to provide such a conductor construction which is capable of long life in overhead transmission line use by reducing the amplitude

of wind induced vibrations, and by drastically reducing the wear resulting from vibrations.

These and other objects and advantages of the invention will be more fully understood as a detailed description of presently preferred embodiments of the invention are set forth hereinafter, with reference to the appended drawings, in which:

FIG. 1 is a perspective view of a conductor according to the invention including a first embodiment of a core element and a first embodiment of a sheath element;

FIG. 2 is a cross-sectional view of the conductor shown in FIG. 1;

FIG. 3 is a cross-sectional view of a second embodiment of a sheath element forming a part of a conductor construction according to the invention;

FIG. 4 is a second embodiment of a core element forming a part of a conductor construction according to the invention;

FIG. 5 is a third embodiment of a core element forming a part of a conductor construction according to the invention;

FIG. 6 is a fourth embodiment of a core element forming a part of a conductor construction according to the invention;

FIG. 7 is a fifth embodiment of a core element forming a part of a conductor construction according to the invention;

FIG. 8 is a sixth embodiment of a core element forming a part of a conductor construction according to the invention; and

FIG. 9 is a seventh embodiment of a core element forming a part of a conductor construction according to the invention.

Referring now to the figures, and particularly to FIGS. 1 and 2, there is shown a conductor construction according to the invention. A multi-wire core indicated generally at **10** is loosely contained within a multi-wire sheath indicated generally at **50**, the sheath **50** encircling the core **10**. For the practice of the invention, a loose core is at least 50 mils smaller in maximum outer diameter than the minimum inner diameter of the sheath. It has been found that at least this much gap or looseness is necessary for clashing as taught herein. In general, it is preferred to keep this gap as small as possible subject to the aforesaid minimum, for economy. However, larger gaps, e.g. with proportions as illustrated in the figures, are fully operative.

In the embodiment of FIGS. 1 and 2, the core **10** includes a substantially smooth cylindrical outer surface **11** and the sheath **50** includes a substantially smooth cylindrical inner surface **51**. It should be understood that the practice of the invention requires only that at least one of the core and the sheath have a smooth cylindrical surface such as **11** or **51**. If for example, the core **10** includes a substantially smooth cylindrical outer surface **11**, then the inner surface **51** of the sheath **50** may be other than smooth, i.e. may include the normal undulated outline formed by a plurality of circular-cylindrical wires. The reverse is also true, i.e. if surface **51** is substantially smooth, surface **11** may include the normal undulated outline of circular-cylindrical wires. For purposes of economy of illustration, only cores and sheaths having substantially smooth cylindrical outer and inner surfaces respectively are shown. Such substantially smooth cylindrical surfaced cores and sheaths may be employed together, as is shown in FIGS. 1 and 2, and they each may also be employed with a mating core or sheath having the aforesaid normal undulated surface resulting from the plurality of circular-cylindrical wires.

Referring now to FIGS. 1–3, two alternative embodiments of a sheath including a substantially smooth cylindrical inner surface will now be described. The first embodiment, being sheath **50** shown in FIGS. 1 and 2, includes a plurality of sheath conductor wires **52**, helically wound in a first direction to form a first conductor wire sheath cylinder, and a second plurality of sheath conductor wires **53** helically wound in a second direction, which is generally, but not necessarily, opposite to the direction of wires **52**, to form an outer cylinder of wires **53** in peripheral contact with the outside surface of the cylinder of wires **52**. Normal practice is to fabricate the sheath wires, e.g. conductor wires **52** and **53**, in a relatively soft material such as aluminum, and this may be accomplished with the present invention also, if desired. In this embodiment, the wires **53** may be shaped, or may be unshaped, as illustrated. By unshaped is meant a wire having the usual circular cross-section.

The shaped conductor wires **52** are each generally shaped as truncated sectors, so that the plurality of shaped conductor wires **52** are fitted together to form a continuous circular tube of wires **52** having a substantially smooth cylindrical inner surface **51** as aforesaid. That is to say, each of wires **52** includes an inner surface **54** which lies along a portion of inner surface **51**. A pair of tapered side surfaces **55**, **56** lie on either side of surface **54** and coincide with radii of cylindrical inner surface **51**.

Conductor wires **52** may be placed by stranding them over a mandrel (not shown) having the diameter of inner surface **51** while constrained by a die (not shown) sufficiently small in diameter to force the initially circular-cylindrical wires **52** to assume the illustrated configuration. As a result of this procedure the outer surface **57** of each wire **52** will also coincide with an arc portion of a cylindrical surface, in this case being the outer cylindrical surface of the plurality of conductor wires **52**. The result is that a substantially smooth inner cylindrical surface **51** is presented by the conductor wires **52**, so that wear with the core element **10** is prevented, even when the core element is undulated as aforesaid. The outer cylinder of conductor wires **53** is added to the inner cylinder of conductor wires **52** to increase the cross-sectional area of the sheath **50** to any desired extent, and these outer wires need not be shaped to a configuration other than circular-cylindrical.

In the second embodiment of a sheath according to the invention, being sheath **50*a*** in FIG. 3, an inner cylindrical tube **70** is presented, having a substantially cylindrical inner surface **51*a*** corresponding to inner surface **51** of the first embodiment. An inner cylinder of conductor wires **52*a*** is wound in a first direction around the outer surface **70*a*** of tube **70**, and an outer cylinder of conductor wires **53*a*** is wound in a second direction around and in contact with the outer perimeter of the plurality of conductor wires **52*a***. In this embodiment the plurality of conductor wires **52*a*** are unshaped, i.e. retain their circular cross-section. The plurality of conductor wires **53*a*** are also unshaped, just as they are in the first sheath embodiment. Thus, in the present embodiment, all the sheath conductor wires are unshaped, and the inner surface **51*a*** is presented by the tube **70**.

Referring now to FIGS. 4–9, and to FIGS. 1–2, there are shown seven embodiments of a core element according to the invention. In the first embodiment of FIGS. 1 and 2, being core element **10**, a cylindrical steel conductor **12** is surrounded by a plurality of conductor wires **13**. These conductor wires **13** may be fabricated in steel, or preferably may be fabricated in aluminum or another relatively soft conductor material. The steel conductor wire **12** is of course a structural element, and under some circumstances the diameter of conductor wire **12** may be increased appreciably to provide increased load capacity, or it may be desired to fabricate the conductor wires **13** in steel to help bear such loads. However, it may be preferred as aforesaid to choose an appropriate diameter for conductor wire **12**, and to fabricate the wires **13** in aluminum or some other material.

Each of conductor wires **13** is shaped to the same configuration as has already been described with respect to sheath conductor wires **52**. The core **10** of this first embodiment may therefore be fabricated by drawing steel

conductor **12**, surrounded by a plurality of initially circular-cylindrical conductor wires **13**, through a die having a sufficiently small diameter such that the conductor wires **13** are deformed to the shape indicated in FIGS. 1 and 2, or by otherwise so forming them. When they are so deformed, conductor wires **13** will give a substantially smooth cylindrical outer surface **11** to core **10**. As has already been explained, a core **10** having such an outer surface **11** may be employed either with a sheath having a smooth inner surface or with a sheath having the normal undulated inner surface resulting from the normal circular cross-section sheath wires, and in either case the wear of both the sheath and the core **10** will be very drastically reduced.

In FIG. 4 there is shown a second embodiment of a core element according to the invention, indicated as core element **10***a*. In this second embodiment, a central steel conductor wire **12***a* is employed, together with a peripheral plurality of conductor wires **13***a*, all as already described with reference to the first embodiment of FIGS. 1 and 2. In addition, a thin-walled cylindrical tube **15** is fitted about the outer perimeter of conductor wires **13**, and the outer surface of tube **15** thereby provides the substantially smooth outer surface **11***a* of core element **10***a*. This second embodiment of a core element according to the invention may be fabricated in the manner already described with reference to the first core embodiment of FIGS. 1 and 2, with the additional provision that tube **15** may either be drawn through the die together with the conductor wires **12***a*, **13***a*, or may be drawn over the conductor wires **12***a*, **13***a* after they have been drawn through the die, or may be extruded over conductor wires **12***a*, **13***a*.

Referring now to FIGS. 5–7, there are shown the third, fourth and fifth embodiments of a core element according to the invention. In FIG. 5, a steel conductor wire **12***b* is surrounded by a plurality of conductor wires **13***b*, which conductor wires **13***b* may be chosen from any desired conductor metal, e.g. steel or a material such as aluminum. Around the outer periphery of conductor wires **13***b* is arranged a plurality of shaped conductors **14**, each of which is approximately in the configuration of a truncated sector. The embodiment of FIG. 5 can be assembled by stranding and forming a plurality of initially circular-cylindrical conductor wires **14** to shape the conductor wires **14** so that they present a substantially smooth outer surface **11***b*. As has already been explained with reference to other embodiments, each layer of conductor wires may be counterwound with respect to radially adjacent layers. In the embodiment shown in FIG. 6, a steel conductor wire **12***c* is surrounded by a plurality of conductor wires **13***c* just as has been described with reference to the embodiment of FIG. 5. In this embodiment a smaller number of outer conductor wires **14***a* is employed, and these conductor wires **14***a* have a much larger initial diameter than those employed in the embodiment of FIG. 5. In this embodiment, the combination of wires **12***c*, **13***c* is drawn through a die with the plurality of initially circular-cylindrical conductor wires **14***a* spaced around the periphery thereof. This drawing process shapes the larger diameter conductor wires **14***a* so that portions thereof are pressed into the undulations formed by the plurality of conductor wires **13***c*, and so that a substantially smooth outer surface **11***c* is presented by the outermost portions of the shaped conductor wires **14***a*. In the embodiment of FIG. 7 a central steel conductor wire **12***d* is surrounded by a plurality of conductor wires **13***d*, in the manner already described with reference to the embodiments of FIGS. 5 and 6. In this embodiment a plastic or metallic material **20** is extruded or otherwise formed onto the outer periphery of conductor wires **13***d* to form substantially smooth outer surface **11***d* of core element **10***d*.

In the embodiment shown in FIG. 8, core element **10***e* includes a central steel conductor wire **12***e* surrounded by a plurality of conductor wires **13***e* and a second plurality of conductor wires **14***b*. As illustrated, the conductor wires **13***e*, **14***b* alternate about the periphery of the central steel conductor wire **12***e*. The conductor wires **13***e* can be fabricated in relatively hard material, and the conductor wires **14***b* can be fabricated in a relatively soft or ductile material. For example, the conductor wires **13***e* may be either steel or a relatively hard aluminum, while the conductor wires **14***b* may be a relatively soft aluminum or another ductile material. The conductor wires **14***b* are shaped to conform to the adjacent conductors **13***e* and also to the central conductor **12***e*. This may be accomplished by drawing the conductor wires **12***e*, **13***e*, **14***b* together through a die which forces the more ductile initially circular-cylindrical conductors **14***b* between adjacent conductor wires **13***e* and ultimately into contact with the central conductor wire **12***e*, while forcing the outermost portion of each of conductor wires **14***b* to assume the cylindrical form of the die, so that the plurality of shaped conductor wires **14***b* define, together with the radially outermost portions of conductor wires **13***e*, a substantially smooth cylindrical outer surface **11***e* of core element **10***e*. This arrangement is also very well suited to making the inner layer of the outer sheath. In addition to the usual effect of the helical winding of the conductor wires, the conductor wires **14***b* of the embodiment of FIG. 8 are interlocked, by virtue of their shape, with conductor wires **13***e*.

In the seventh embodiment shown in FIG. 9, a core element **10***f* comprises an inner steel conductor wire **12***f* surrounded by a plurality of interlocking conductor wires **13***f*. Remembering that the conductor wires **13***f* are helically wound on the central conductor wire **12***f*, it will be appreciated that the conductor wires **13***f* are shaped so as to be interlocked one with the other so that individual ones thereof are held closely to center conductor wire **12***f* despite any tendencies to buckle away therefrom. In the illustrated embodiment of FIG. 9 this locking is accomplished by an inner shaped lateral lobe **25** on each conductor wire **13***f*, which is matched by a lateral indentation **26** in the opposite face of each conductor wire **13***f*. Accordingly each lateral lobe **25** is locked into a lateral indentation **26** of its neighbor, and the assembly of conductor wires **13***f* is helically locked in place against central conductor wire **12***f*. It is contemplated that conductor wires **13***f* may be specially fabricated in steel to the illustrated shape, and may be wound as such onto center steel conductor wire **12***f*. Of course, the conductor wires **13***f* could be also be fabricated in a softer material such as aluminum. In any event the outermost portion of each of conductor wires **13***f* are arc-portions, and the plurality of conductor wires **13***f* accordingly forms a substantially smooth cylindrical outer surface **11***f* of the core element **10***f*.

What has been described is a plurality of embodiments of a sheath conductor element having a substantially smooth cylindrical inner surface, which, when employed with the usual core element having undulations at the outer surface thereof due to the circular-cylindrical conguration of the conductor wires comprising the multi-wire core, does not cause scoring or wearing away of either the core or the sheath or wearing away of any coating material on either the inner surface of the sheath or the outer surface of the core. Also, a plurality of embodiments of a multi-wire core conductor element has been shown having a substantially smooth cylindrical outer surface, such that when employed with the usual sheath conductor having an undulating inner surface resultant from the plurality of circular-cylindrical conductors forming that inner surface, wear or scoring of either the core element or the sheath element is prevented. Of course, as has already been mentioned, a core element having a substantially smooth cylindrical outer surface according to the invention may be employed together with a sheath conductor element having a substantially

smooth cylindrical inner surface according to the invention, and still less wear will occur. It is essential to the practice of the invention that one of the multi-wire elements, i.e. either the core element or the sheath element, have a substantially smooth cylindrical face in contact with the other element, but it is preferred that both the core element and the sheath element have such substantially smooth contact surfaces.

It will be recognized that an electrical conductor according to the invention provides damping of aeolian vibrations and of galloping by clashing of the sheath element with the core element, but without the appreciable wear which has heretofore characterized such arrangements. For example, a sheath similar to that shown in FIG. 3, but without the cylindrical tube **70**, was fitted with a core similar to that shown in FIG. 5, but without the smooth outer surfaced conductor elements **14**, so that both the sheath element and the core element included facing surfaces which were comprised of circular-cylindrical conductor wires presenting counterwound opposed undulating surfaces. After a period of only 12 days, during which there occurred approximately ten million cycles of vibration, the electrical conductor was inspected, and it was seen that the steel core conductor wires had been deprived of their zinc coating through mechanical action and had themselves cut into the aluminum sheath conductor wires to a depth of about ten mils. Another conductor was made up employing the exact same kind of sheath element, but employing a core element such as that shown in the first core embodiment of FIGS. 1 and 2. After the same period of time and approximate cycles of service, this electrical conductor was inspected and the wear was barely visible, that is to say, to all intents and purposes there was no wear. The savings in maintenance and replacement which result from the present invention are very large. More important, conductor failures, either structural or electrical, are greatly reduced by employment of the present invention, thus increasing reliability of power transmission lines.

While the invention has been described with reference to certain specific embodiments, this description has been illustrative, not limiting. Those skilled in the art will appreciate the variations and modifications from the illustrated embodiments that may be practiced within the scope of the invention.

What is claimed is:

1. In a cable useful in an overhead transmission line, including a multi-stranded core having a steel portion to bear the preponderance of the cable tension forces, and a multi-wire sheath surrounding the core and spaced radially therefrom so that the core is loose within the sheath, the sheath wires being fabricated in a metal which is a good electrical conductor but which is softer than

steel, the improvement in combination therewith, comprising:

(a) a layer of metal forming a part of said core and surrounding the steel portion of said core, said metal being substantially as soft as the conductor metal employed in said sheath, and the outer surface of said metal layer being substantially smooth in outline;

(b) an innermost layer of wires forming a part of said sheath, having cooperating surfaces mutually forming a smooth inner surface of said sheath, the smooth inner surface of said sheath being spaced at least 50 mils in difference of diameter from the smooth outer surface of said core, so that said core is loose within said sheath.

2. A cable according to claim **1** wherein the metal layer of said core surrounding said steel portion comprises aluminum, and wherein the wires of said sheath forming the inner layer thereof also comprise aluminum.

3. A cable according to claim **1** wherein said metal layer of said core surrounding the steel portion thereof comprises a plurality of aluminum wires, having mutually cooperating surfaces forming the said smooth outer surface of the core, and wherein the inner layer of wires of said sheath comprises aluminum.

4. A cable according to claim **1** wherein the metal layer of said core surrounding the steel portion thereof comprises a plurality of aluminum wires, each having a cross-section which is substantially that of a truncated sector, the sector-wires being arranged side by side around the periphery of the steel portion with their individual outer surfaces cooperating to define the said smooth outer surface of the core, and wherein the said innermost layer of wires forming part of the sheath comprises individual wires each having a cross-section substantially that of a truncated sector, the sector-wires being arranged side by side thereby mutually forming the said smooth inner surface of the sheath.

References Cited

UNITED STATES PATENTS

2,050,298	8/1936	Everett.
3,264,404	8/1966	Trebby et al. ---------- 174—130

FOREIGN PATENTS

22,886	10/1930	Australia.
640,818	4/1928	France.
771,623	7/1934	France.
800,635	5/1936	France.
902,744	1/1954	Germany.
575,792	4/1958	Italy.

LARAMIE E. ASKIN, *Primary Examiner.*

U.S. Cl. X.R.

174—42