

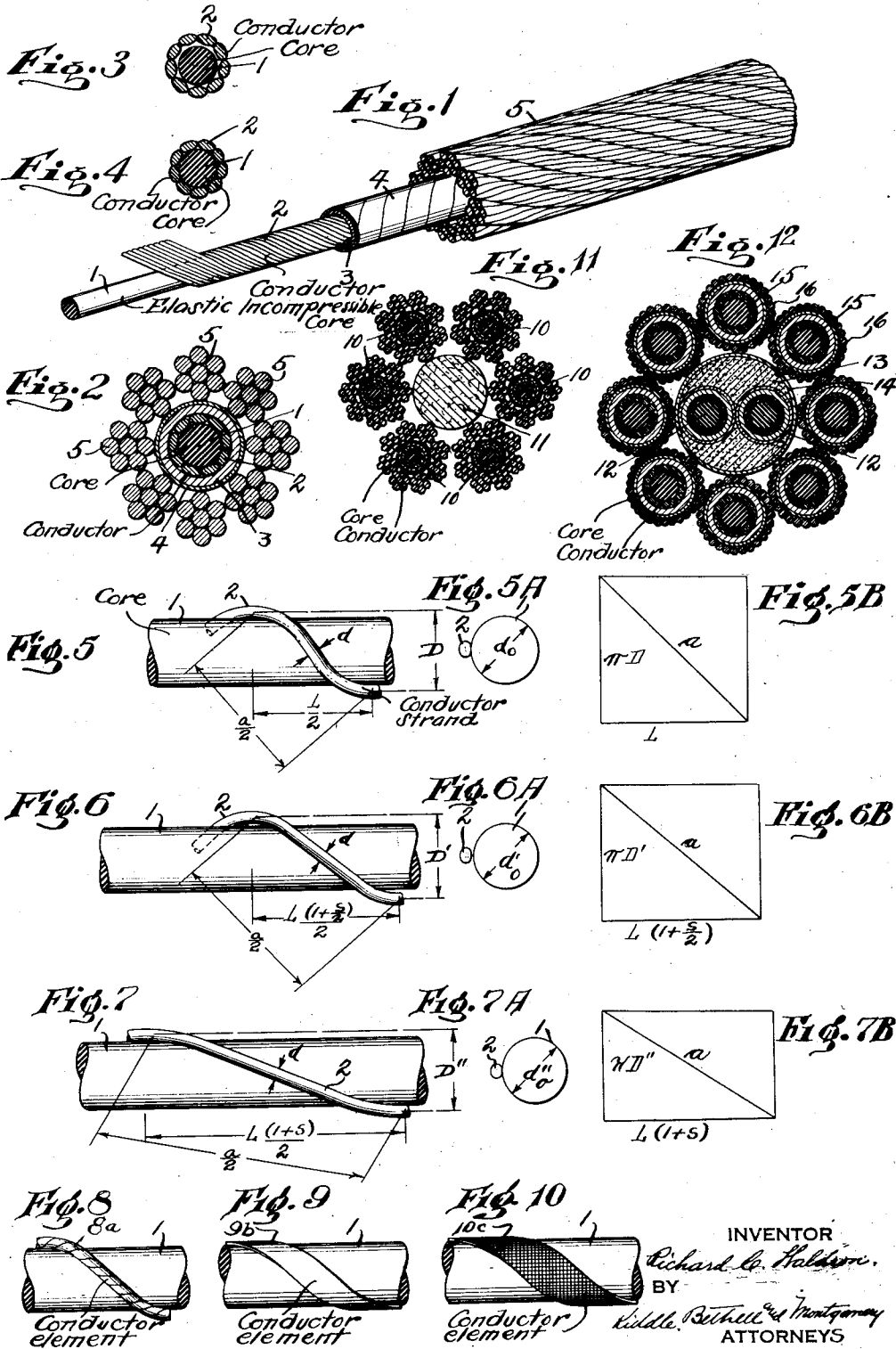
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ELECTRIC CABLE

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## UNITED STATES PATENT OFFICE

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## ELECTRIC CABLE

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6 Claims. (Cl. 173-266)

This invention is directed to an improvement in electric cables and is primarily directed to providing an electric cable construction which is particularly well adapted for vertical suspension in long lengths.

The increasing use of electric cables in long lengths for vertical suspension, as in exploration of oil wells, for example, has resulted in a demand for a conductor which will elongate and contract without breaking. The usual conductor cannot be used as stretching so elongates the copper conductor permanently that when the tension is removed and the cable contracts buckling of the conductor results. Repetition of this action results in breaking of the conductor. This elongation cannot be overcome with the usual types of steel armor employed, inasmuch as the conductor is small and of little strength as compared with the armor, so that it must elongate and contract with the armor.

The present invention provides a construction in which the conductor will stretch and contract with the cable without deformation. My copending application Serial No. 59,204, filed January 15, 1936, discloses a construction in which stretching of the conductor is so controlled that the cable can be elongated and returned to its original length without buckling and breaking of the conductor.

In the accompanying drawing:

Fig. 1 is a part sectional view of a cable embodying my invention;

Fig. 2 is a cross section of the cable of Fig. 1;

Figs. 3 and 4 are cross-sectional views illustrating the relative positions of the cable conductor and core at different stages of elongation of the cable;

Fig. 5 shows one strand of the unstretched cable conductor about a core of extensible substantially incompressible material;

Fig. 5A is an end view of the structure of Fig. 5;

Fig. 5B is a development of a cylinder whose diameter is the pitch diameter of the strand of Fig. 5 and whose length is the length of lay of the strand of Fig. 5;

Fig. 6 shows the core and strand of Fig. 5 with the cable in partially stretched condition;

Fig. 6A is an end view of Fig. 6;

Fig. 6B is a development of a cylinder whose diameter is the pitch diameter of the strand of Fig. 6 and whose length is the length of lay of the strand of Fig. 6;

Fig. 7 shows the core and strand of Fig. 5 with the core fully stretched;

Fig. 7A is an end view of Fig. 7;

Fig. 7B is a development of a cylinder whose diameter is the pitch diameter of the strand of Fig. 7 and whose length is the length of lay of the strand of Fig. 7;

Fig. 8 shows one type of conductor which may be employed in the practice of my invention;

Fig. 9 shows another type of conductor; and Fig. 10 shows still another type;

Figs. 11 and 12 are cross sectional views of modified embodiments of my invention, employing several conductors about a common center or core.

Referring to the drawing in detail, and first of all to the construction illustrated in Figs. 1 to 7B inclusive. 1 designates the core of my improved cable. This core is a pliable, extensible, substantially incompressible material such as rubber, or a fibrous material such as silk or cotton threads, for example, twisted together so as to be sufficiently incompressible for my purpose and yet at the same time extensible and pliable.

About this extensible, substantially incompressible core I apply the conductor 2. This conductor, in this embodiment of my invention, is composed of copper strands helically applied in parallel relation in a predetermined lay about the incompressible extensible core as will be brought out in detail hereinafter.

Directly over the conductor 2 I apply insulation 3, which may be the usual rubber or rubber compound insulation commonly employed in electric cable work.

About the insulation 3 I apply a fabric covering 4 which may be saturated with oil and moisture impervious material, such as Harvel, an acid condensation product made from the oil obtained from cashew nut shells.

5 designates a supporting armor consisting of stranded steel wire. These steel wires are the same as commonly employed for steel wire rope and may be laid up in any of the methods common to wire rope manufacture.

As pointed out at the outset of this description, the conductor 2 has little strength as compared with the armor 5 and unless means are provided to prevent it, the conductor must elongate and contract with stretching of the cable with the result that the conductor buckles and in a short time breaks.

I propose to overcome this defect by applying the conductor in a predetermined lay about an extensible, substantially incompressible core.

Referring now more particularly to Figs. 5 through 7B, Figs. 5 and 5A show the initial position of each conductor strand;

In Figs. 5 and 5A—initial position of each conductor strand:

$d_o$  = the diameter of the core 1

$d$  = diameter of each strand of the conductor 2

$D$  = pitch diameter of each strand of the conductor

$= d_o + d$

$L$  = length of lay of each strand of the conductor

$a$  = length of each conductor strand for one complete turn about the core 1

In Figs. 6 and 6A—partially stretched condition of the strands of the conductor 2:

$d_o'$  = diameter of core 1 under the assumed conditions

$D'$  = pitch diameter of each strand of the conductor 2 under assumed partially stretched condition

$s$  = percentage elongation (in decimal) for which the cable is designed

In Figs. 7 and 7A—the conductor stretched to the limit for which it is designed:

$d_o''$  = diameter of core 1 under the assumed conditions

$D''$  = pitch diameter of each strand of the conductor 2 under the assumed conditions

The conductor 2 is so designed that at the initial and extended positions it lies snugly on the core 1, as illustrated in Figs. 5A and 7A. Intermediate these positions the conductor is out of contact with the core, as illustrated in Fig. 6A. Fig. 3 illustrates an intermediate condition corresponding to Fig. 6A, and Fig. 4 a condition corresponding to Fig. 7A.

These conditions exist only for a definite lay of the conductor as determined by the formula

$$(1) L = \pi \sqrt{\frac{d_o}{s(2+s)}} \left[ d_o \left( 1 - \frac{1}{1+s} \right) + 2d \left( 1 - \sqrt{\frac{1}{1+s}} \right) \right]$$

The above formula is directly concerned with cables having a rubber core, such a core being ideal in that while it is pliable and extensible it is substantially incompressible. As above indicated fibrous cores may be employed with good results, offering sufficient support for the conductor, so far as incompressibility is concerned, and elongating and contracting sufficiently without breaking.

However, metal cores either solid or stranded may be employed if desired for small elongations.

For small values of  $s$  the following formula may be used:

$$(2) L = \pi \sqrt{\frac{d_o^2 + d^2}{(s+2)(s+1)}}$$

In designing a cable for a given service and knowing the diameter of the conductor strands, the initial size of the core of the cable and elongation desired, the lay of the conductor strands about the core is determined by Formula (1) given above for large values of  $s$  or elongation, or Formula (2) for small values of  $s$ . Under those conditions and with the conductor laid about the core in accordance with Formula (1) or Formula (2), initially the conductor strands are in contact with the core as shown in Fig. 5A, for instance, and on initial stretching of the cable the core is reduced in diameter faster than the pitch diameter of the conductor strands so that the core moves away from the conductor strands, as illustrated in Figs. 3 and 6A; while at maximum elongation for which the cable is designed which of course should not exceed the maximum elongation which the core will withstand without

breaking the conductor strands again contact with the incompressible core, as illustrated in Figs. 4 and 7A.

The pitch diameter of the conductor strands may be readily determined for any elongation desired.

For example:

Let it be required to find the pitch diameter of the conductor helix for an elongation equal to  $x\%$  where  $x$  may be either smaller or greater than unity:

Let  $D_x$  = pitch diameter

$a$  = strand length which is constant throughout

$s$  = elongation for which cable is designed

$D$  = original pitch diameter

$L$  = lay determined from Formula (1)

Then

$$D_x = \frac{1}{\pi} \sqrt{a^2 - L^2(1+x)^2}$$

or

$$d_{ox} = D_x - d = \frac{1}{\pi} \sqrt{a^2 - L^2(1+x)^2} - d$$

also

$$d_{ox} = d_o \sqrt{\frac{1}{1+s}}$$

From these two equations it may be seen whether the strand will be loose or tight on the core. It can readily be seen that if  $d_{ox}$ , calculated by the first equation is smaller than if calculated by the second, stretching of the strand or distortion of the core must take place.

It is to be understood that the conductor may be made up of a number of strands lying side by side and disposed about the core in parallel

relation as illustrated in Fig. 1; or the conductor may be in the form of a group of strands previously twisted together as illustrated at 8a in Fig. 8; or the conductor may be in the form of a tape as illustrated at 9b in Fig. 9; or a woven or braided tape as illustrated at 10c in Fig. 10.

When the conductor is in the form of a tape or braid as illustrated at 9b and 10c the thickness of the same is used in calculating the lay from Formula (1) or Formula (2).

The above description has been made with reference to cables with a single insulated conductor. Where a cable is desired composed of a plurality of insulated conductors I may employ a construction such as illustrated in Fig. 11 wherein a plurality of armored cables 10 are laid up about a center 11. This center may be of any of the well known types of centers used in steel wire rope, such as hemp for example. In this embodiment of my invention, each cable 10 is a duplicate of the construction illustrated in Figs. 1 and 2. It is to be understood that the supporting armor wires need not necessarily be made up of strands as shown but may be solid wire.

A further modification of a multi-conductor cable embodying my invention is illustrated in Fig. 12 where two cables 12 similar to the cable structure of Fig. 2, but without supporting armor wires are twisted together, and a circular cross section built up of jute 13, for example, surrounded by a tape or belt 14. A plurality of cables 15, duplicates of that shown in Figs. 1 and 2, are laid up around these central cables. In

this embodiment of my invention the supporting armor wires 16 have been shown solid.

It will be seen from all of the foregoing that the present invention provides an electric cable construction in which the conductor is laid up about a substantially incompressible, extensible core with such a lay that upon initial elongation the outside diameter of the core decreases faster than the inside diameter of the conductor helix, so that the core moves away from the conductor, while on continued elongation a point will be reached where the inside diameter of the conductor helix decreases faster than the outside diameter of the core to cause the conductor to reengage the core on maximum elongation which of course should not exceed the breaking point of the core.

To show the superiority of cables constructed in accordance with my invention over cables constructed according to prior practice, I have made a number of comparative tests using a single conductor cable. These tests in all cases essentially involved subjecting a sample of freely suspended cable to a two ton load so that the cable elongates. The tension on the cable is then relieved permitting the cable to return to its original position.

The usual type of conductor made up of nineteen strands of wire concentrically stranded broke after seventy-eight minutes under this test. The speed of the test was approximately one cycle per minute, corresponding to elongating and contracting the cable seventy-eight times. The conductor failed due to breaking of the copper from flexing, and kinks were found approximately every six inches throughout the test length.

Another test was run employing a cable having the same total copper area as the cable first mentioned, but stranded in what is commonly known as rope stranding, that is, seven bunches of wire, each consisting of seven individual wires were stranded together. After thirty hours this cable failed due to kinking of the conductor, and kinks were found every four to six inches throughout the test length.

The same test was then run on the cable of Fig. 1 of my application, employing an extensible incompressible core and a conductor of five wires stranded and applied about the core with the lay I have hereinabove described. This cable withstood a total of two hundred and ten hours without the conductor breaking, the steel supporting wires shown at 5 in Fig. 1 breaking due to fatigue on the steel. This test shows that my improved cable is at least seven times as good as the old structures, and as a matter of fact at the end of the two hundred and ten hours the conductor showed no signs of kinking nor of failure.

What I claim is:—

1. An extensible electric cable comprising in combination a core of extensible, substantially incompressible material, a conductor helically applied about and in contact with said core with such a lay that initial elongation of the cable will tend to bring the core out of contact with the conductor so that maximum extension of the cable is permitted without permanent distortion of the conductor, attempted further elongation causing the conductor to re-engage the surface

of said core and to become permanently distorted.

2. An electric cable comprising in combination a core of extensible, substantially incompressible material, a conductor helically applied about said core and in contact therewith, the lay of said conductor being such that upon initial elongation of the cable the outside diameter of the core will decrease faster than the inside diameter of the conductor helix, further elongation of the cable eventually causing the conductor helix to decrease in diameter faster than the outside diameter of the core finally to re-engage the core, attempted further elongation of the cable causing the conductor to become permanently distorted.

3. An extensible electric cable comprising in combination a core of extensible, substantially incompressible material, a conductor helically applied about and in contact with said core with such a lay that extension of the cable from zero extension to maximum extension is permitted without permanent distortion of the conductor, attempted further elongation causing the conductor to engage the surface of said incompressible core and to become permanently distorted, insulation about the conductor and supporting wires about said insulation.

4. A multi-conductor electric cable comprising in combination a plurality of single conductor cables disposed about a central core, each single conductor cable comprising a core of extensible, substantially incompressible material and a conductor helically applied about said core and in contact therewith with such a lay that extension of the cable from zero to maximum extension is permitted without permanent distortion of the conductor, attempted further elongation of the cable causing the conductor to engage the core and to become permanently distorted, and armor supporting wire for each cable.

5. A multi-conductor cable comprising in combination a plurality of single conductor cables twisted together and each composed of a core of extensible, substantially incompressible material, a conductor helically applied about the core with such a lay that extension of the cable from zero extension to maximum extension is permitted without permanent distortion of the conductor, attempted further elongation causing the conductor to engage the surface of said incompressible core and to become permanently distorted, a plurality of similar single conductor cables laid up about said first mentioned cables, each of the last mentioned cables being enclosed in supporting wires.

6. An extensible electric cable comprising in combination a core of extensible, substantially incompressible material, a conductor helically applied about and in contact with said core with such a lay that initial elongation of the cable will tend to bring the core out of contact with the conductor so that extension of the cable up to the breaking point of the core is permitted without permanent distortion of the conductor, attempted further elongation causing the conductor to reengage the surface of said core and to become permanently distorted.

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