

[54] COMPACT CONDUCTOR

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[51] Int. Cl. H01b 5/08

[58] Field of Search 174/128, 129 R, 130

[56] References Cited

UNITED STATES PATENTS

587,764 8/1897 Short 174/129 R

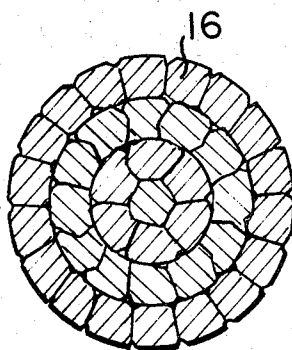
1,943,087 1/1934 Potter 174/128 X
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Primary Examiner—E. A. Goldberg
Attorney—Victor F. Volk

[57] ABSTRACT

Improved electrical conductor is formed by compacting concentric conductors which have outside wires with gages at least equal to the gages of the inside wires. Such a conductor with 37 or more wires may have the outer layer only, made up of square wires.

5 Claims, 3 Drawing Figures



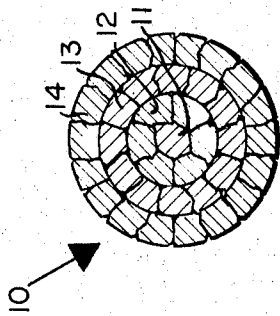


Fig. 1

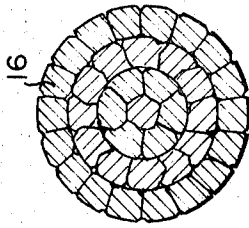


Fig. 2

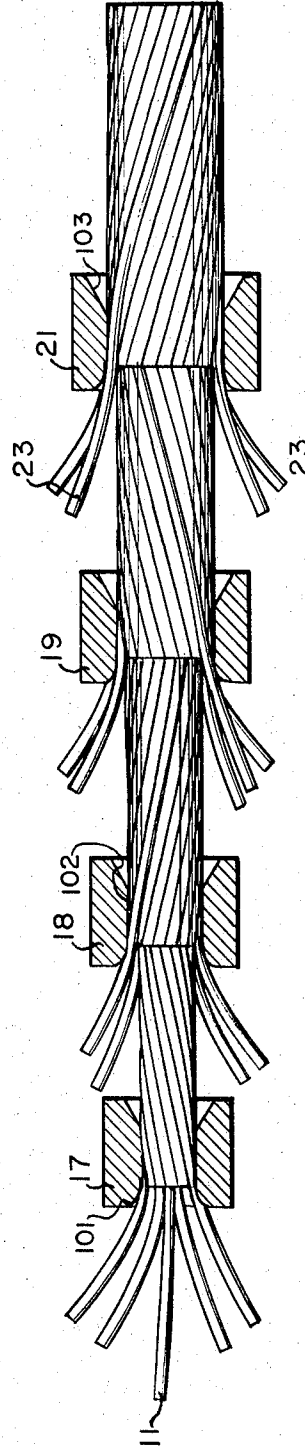


Fig. 3

COMPACT CONDUCTOR

BACKGROUND OF THE INVENTION

The conductors of electric cables are customarily made by stranding together a plurality of wires in concentric layers. The geometry of the cable cross section is naturally such that six wires will fit firmly around a single center wire, twelve wires will fit around the six, eighteen wires around the twelve, etc. each layer having six more wires than the underlying layer. Conductors made up in this manner are known as concentric lay conductors and are described in a number of industry standards, such as American Society for Testing Materials (ASTM) B 8-70. The number of wires in such a concentric lay conductor will equal exactly $3n^2 + 3n + 1$ where n represents the number of layers surrounding the central wire. Concentric lay conductors, however, have large overall diameters for a given conductance, or cross section of metal, caused by the many open spaces or interstices between the wires. To reduce the conductor diameter it has been known to crush or compact the wires after the layers have been applied, so as to force some of the metal into the interstices. Conductors with wires so crushed are known as compact round conductors. U.S. Pat. No. 1,943,087, which issued in 1934, is still fairly representative of the state of the art of compact round conductors and a number of industry standards, such as ASTM B 496-69 describe them. Compacting of a standard conductor, however, changes the geometrical dimensional relationships so that a layer with six more wires than the underlying layer no longer fits naturally onto the conductor. The aforementioned compact conductor patent teaches, and the teaching has been generally followed in commerce, that, to compensate for the reduction in diameter of the conductor core by compacting, the individual diameters of wires in succeeding layers should be reduced. This has had the significant manufacturing advantage that all the reel carriers of the stranding machines are utilized, but it has also had the serious disadvantage that many different wire sizes are required to be drawn and stocked. Another disadvantageous practice of the known art of making compact round conductors, as followed in commerce, and as taught by the early patent, has been the necessity to reduce the length of stranding lay substantially below the maximum allowed by ASTM and other industry standards. This is 16 times the diameter for copper (see ASTM B 496-69) and for Class B strand aluminum (see ASTM B 400-70). Shortening of the lay adds significantly to the cost of manufacturing since it reduces the hourly production of the stranding machines.

The aforementioned patent taught the art of compacting conductors by means of pressure rolls. More recently it has been known that it is also feasible to effect the compacting by pulling the conductor through a wire drawing type die after the application of each layer of wires, but conductors made by either method, using industry teachings for the selection of wire sizes and lay lengths, have been characterized by wide variations of temper, due to uneven work hardening, through the conductor section. Typically, the more central wires have been excessively hardened. When such conductors are flexed or tensioned the load is not evenly distributed and failure will occur earlier than it would for a conductor of uniform hardness throughout its section.

SUMMARY

I have invented a new compact electrical cable conductor and method that reduces the number of different wire sizes to be drawn and permits a maximum stranding lay for each layer. My conductor has a reduced diameter for a given conductance and a relatively uniform degree of work hardening in each layer. Copper conductor, compacted to my invention, has retained an elongation averaging over 15 percent in each layer, although the diameter is reduced even below that of prior art conductors in which some wires retained elongations of less than 5 percent. My present conductor comprises a central wire and a plurality of layers of helically applied wires surrounding the central wire. An innermost of these layers consists of six wires and each additional layer comprises a plurality of wires six in number greater than the number of wires in the directly underlying layer. The gage of the individual wires in any layer of my conductor is not less than the gage of any underlying wire and the conductor is compacted to a diameter at least 8 percent less than the diameter of a concentric lay conductor of equal circular mil area. Embodiments of my conductor comprise constructions wherein the central wire and all the wires in the layers are round and of the same gage before compacting, and constructions of three or more layers wherein the wires of the outermost layer, only, are square and of a larger gage. In preferred embodiments the wires in my conductor comprise copper and the layers alternate in direction of lay.

My method for making a compact conductor for an electric cable consisting of $3n^2 + 3n + 1$ wires helically wound in n layers over a central of said wires comprises steps of continuously pulling the central wire from a supply thereof through n fixed, linearly mounted, wire drawing type dies, pulling six round wires, of a sectional area at least as large as the sectional area of the central wire from supplies of the same being driven in rotation around the central wire, through a first of the dies, and therein forming a compacted core from the wires. This first die has a minimum aperture no greater than 92 percent of three times the diameter of the central wire. In my method I also pull twelve round wires each having a sectional area at least as large as the sectional area of one of the six wires, from supplies driven in rotation around the core through a second of the dies therein compacting the wires and enlarging the core. This second die has a minimum aperture no greater than 92 percent of five times the diameter of the central wire. For each of any additional layers I pull a plurality of wires six in number greater than the number of wires in the next underlying layer through one of the plurality of dies having a minimum aperture no larger than 92 percent of $(2m + 1)$ times the diameter of the central wire where m represents the layer number. Each of these additional layer wires is at least as large in sectional area as any of the underlying wires and is pulled from supplies being driven in rotation around the core.

BRIEF DESCRIPTION OF THE DRAWING:

FIG. 1 shows a section of a conductor of my invention.

FIG. 2 shows a section of another embodiment of the conductor of my invention.

FIG. 3 shows steps in the method of my invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

As seen in FIG. 1, a compact conductor of my invention indicated by the numeral 10 has a central wire 11 surrounded by three layers 12, 13, 14 or wire wrapped helically around it. Prior to compacting, the wire 11 and all the wires of the layers 12-14 are round. FIG. 2 shows another embodiment of my conductor differing from that of FIG. 1 by having an outside layer 16 of square wires. An essential feature wherein my conductors differ from prior compact round conductors resides in the fact that the wires of the outer layers 14, 16 are no smaller in cross-section or gage than the wire 11. Beneficially, all the round wires are the same gage. To form the conductor 10 the central wire 11, along with six identical wires of the layer 12, are pulled through a wire drawing type die 17 which compresses or compacts the strand at least 8 percent, creating the sectional appearance of FIGS. 1 and 2, wherein the interstices between the wires have been substantially filled with metal by deforming the initial circular shape of both the wire 11 and the wire of the layer 12. The die 17 and downstream dies 18, 19, 21 to be further described are mounted rigidly in line and the wires are pulled through the dies at a predetermined rate by capstan means, not shown, associated with a stranding machine such as a type of machine known as a rigid strander on which six reels holding supplies of the wires of the layer 12 are rotated around the line of the central wire 11 as the wires are pulled off into the die 17. In a like manner, but in the opposite direction of rotation, 12 round wires of the layer 13 are rotated around a compacted core 22 being pulled into the die 18. Eighteen wires of the layer 14 are rotated to apply a left hand lay into the die 19 completing the conductor 10. The method of FIG. 3 can be applied to an indefinite number of layers as shall be further explained with examples hereinbelow. I have shown the application of an additional layer of 24 wires 23 of the same size as the wire 11 through a wire drawing type die 21 with a right hand lay. It is a feature of my invention that a superior compact conductor can be formed of copper wires with the direction of lay alternated to balance the construction. ASTM B 496-69, the industry standard for compact round copper conductors has followed the teaching of the U.S. Pat. No. 1,943,087 patent that the layers should all have the same direction of lay and my invention, involving the application of full size wires or larger in the outer layers also has advantages for such a unildy construction. It should be noted that ASTM B 400-70, for aluminum compact round conductors has permitted the alternation of layers, presumably because of the softer metal. Example 1, below, typifies a copper conductor made from round wires in accordance with my invention.

EXAMPLE 1

Conductor size, 500 MCM, 37 wires
Diameter of each of the round wires, inch, 0.1247
Aperture of die 17 over six wires, inch, 0.316
Length and direction of lay of six wires, 4.74 inches L.H.
Aperture of die 18 over 12 wires, inch, 0.526
Length and direction of lay of 12 wires, 7.89 inches, R.H.
Aperture of die 19 over 18 wires inch, 0.736

Length and direction of lay of 18 wires, 11.04 inches, L.H.

A detailed consideration of EXAMPLE 1 will clarify some of the features of my invention. The total number of wires are thirty seven and the number of layers over the central wire are three. This corresponds to the formula for a concentric strand, $S = 3n^2 + 3n + 1$, where n represents the number of layers and S the number of wires. The diameter over the second layer of an uncompacted strand would be $(2m + 1)$ times the wire diameter with m equal to 2 or, $5 \times 0.1247 = 0.6235$ inch, the pitch diameter of the next layer would equal $0.6235 + 0.1247$ equals 0.7482 inch. An 18 sided polygon inscribed in a circle of this diameter would have a perimeter of $18 \times 0.7482 \times \sin 10^\circ = 2.326$ inches. The sum of the diameters of 18 strands of 0.1247 inch wires equals 2.245 inches, allowing the 18 strands to fit an uncompacted core with an allowance for the lay angle. In the compacted core of EXAMPLE 1 however, the die 19 has an aperture of only 0.736 inch, if we obtain the pitch diameter by subtracting one wire diameter (0.1247) from this aperture we obtain 0.6113 inch. An 18 sided polygon inscribed in a 0.6113 inch circle will have a perimeter of only $18 \times 0.6113 \times \sin 10^\circ = 1.9107$ inches. Since, as has been stated, the 18 wires require a perimeter of 2.245 inches, they must be crushed together even before entering the die 19. I have found, surprisingly, that it is not only possible to introduce wires of this large diameter, but that so doing produces a more compact conductor and one in which there is no excessive work hardening.

EXAMPLE 2

Conductor size, Awg No. 1/0, 19 wires
Diameter of each round wire, 0.0817 inch
Aperture of die 17 over six wires, 0.204 inch
Lay of six wires, 3.24 inches R.H.
Aperture of die 18 over 12 wires, 0.340 inch
Lay of 12 wires, 5.31 inches L.H.

EXAMPLE 3

Conductor size, Awg No. 2/0, 19 wires
Diameter of each round wire, 0.0915 inch
Aperture of die over six wires, 0.229 inch
Lay of six wires, 3.47 inches R.H.
Aperture of die over 12 wires, 0.382 inch
Lay of twelve wires, 5.93 inches L.H.

EXAMPLE 4

Conductor size, Awg No. 4/0, 19 wires
Diameter of each round wire, 0.1153 inch
Aperture of die over six wires, 0.288 inch
Lay of six wires, 4.06 inches R.H.
Aperture of die over 12 wires, 0.480 inch
Lay of 12 wires, 7.61 inches L.H.

EXAMPLE 5

Conductor size, 750 MCM, 61 wires
Diameter of each round round wire, 0.1215 inch
Aperture of die over six wires, 0.302 inch
Lay of six wires, 4.53 inches, R.H.
Aperture of die over 12 wires, 0.503 inch
Lay of twelve wires, 7.55 inches L.H.
Aperture of die over 18 wires, 0.705 inch
Lay of eighteen wires, 10.58 inches R.H.
Aperture of die over 24 wires, 0.906 inch
Lay of 24 wires 13.59 inches, L.H.

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I have found that where there are three or more layers over the central wire an increased surface smoothness of the conductor and a lessening of the pulling load of the stranding machine can be achieved by drawing the wires in the outer layer square, instead of round. 5
The same number of wires are used in the layer as would be used for a conventional concentric strand i.e. 6m wires, where m represents the number of layers, and the sectional area of the square wire is at least as great as any of the other wires in the conductor, in fact, 10
I prefer to increase the area in the square wires as illustrated in EXAMPLES 6-10 below.

EXAMPLE 6

Conductor size, 250 MCM 37 wires
Diameter of each round wire 0.0855 inch, area 0.005741 in²
Aperture of die over six wires, 0.228 inch
Aperture of die over 12 wires, 0.380 inch
Lay of 12 wires, 5.89 inches, R.H.
Side of square wires 0.0794 inch, area 0.005961* in² 20
Aperture of die over 18 square wires, 0.522 inch
Lay of 18 wires 8.04 inches, L.H.
* deducted for rounded corners per ASTM B 48-68

The square wire layer is compacted at least 8 percent by the wire drawing type die as are the round wires of all my novel conductors. Thus, considering the conductor of EXAMPLE 6, the diameter of the 12-wire die is 0.380 inch. Over this is applied a layer of square wires 0.0794 inch on a side which would increase the diameter of the core to 0.5378 inch. But the final die is only 0.522 inch, permitting a radial increase of only 0.071 inch instead of 0.0794. These teachings will also be seen to apply to the EXAMPLES following.

EXAMPLE 7

Conductor size, 350 MCM, 37 wires
Diameter of each round wire, 0.1010 inch
Die aperture over six wires, 0.270 inch
Die aperture over 12 wires, 0.450 inch
Lay of 12 wires, 6.90 inches, R.H.
Side of square wires 0.0940 inch
Die aperture over 18 square wires 0.616 inch
Lay of square wires, 9.57 inches, L.H.

EXAMPLE 8

Conductor size, 500 MCM, 37 wires
Diameter of each round wire, 0.1210 inch
Die aperture over six wires, 0.325 inch
Die aperture over 12 wires 0.540 inch
Lay of twelve wires, 8.06 inches R.H.
Side of square wires 0.1120 inch
Die aperture over 18 square wires 0.736 inch
Lay of square wires 11.02 inches, L.H.

EXAMPLE 9

Conductor size, 750 MCM, 61 wires
Diameter of each round wire, 0.1153 inch
Aperture of die over six wires, 0.307 inch
Aperture of die over 12 wires, 0.512 inch
Aperture of die over 18 wires, 0.717 inch

6

Lay of 18 wires 10.57 inches, R.H.
Side of square wires 0.1060 inch
Lay of 24 square wires 14.16 inches L.H.
Die aperture over square wires, 0.906 inch

EXAMPLE 10

Conductor size 1000 MCM, 61 wires
Diameter of each round wire, 0.1330 inch
Aperture of die over six wires, 0.358 inch
Aperture of die over 12 wires, 0.597 inch
Aperture of die over 18 wires, 0.836 inch
Lay of 18 wires, 12.34 inches R.H.
Side of square wires, 0.1225 inch
Die aperture over 24 wires, 10.56 inches
Lay of square wires 16.40 inches L.H.

In addition to the benefits of high production speeds and lower diameters already mentioned, I have found that running compact round conductors with large outside wires has the unexpected result that the strand remains tight on the strander capstan during reel changes, can be stranded without adding oil for lubricant, and gives excellent die wear.

The dies 17, 18, 19, 21 differ from commonly used wire drawing dies in having larger apertures but they are characterized with wire drawing dies in being formed of tungsten carbide or material of similar hardness, having highly polished smooth inner surfaces, widened entrance zones 101, cylindrical or substantially cylindrical lands 102, and, preferably, conical reliefs 103.

I have invented a new and useful compact round conductor for electric cables, and a new method of making such conductor of which the foregoing description has been exemplary rather than definitive and for which I desire an award of Letters Patent as defined in the following claims.

I claim:

1. A conductor for an electric cable comprising:

A. a central wire and a plurality of layers of helically applied wires surrounding said central wire, an innermost of said layers consisting of six wires and each additional layer consisting of a plurality of wires six in number greater than the number of wires in the directly underlying layer,

B. the gage of individual wires in any layer being not less than the gage of any underlying wire, and

C. said conductor being compacted to a diameter at least 8 percent less than the diameter of a concentric lay conductor of equal circular mil area.

2. The cable of claim 1 wherein said central wire and all of said wires in said layers are round and of the same gage before compacting.

3. The cable of claim 1 comprising at least two of said layers of round wires of the same gage as said central wire and an outer of said layers of square wires of a larger gage, before compacting.

4. The cable of claim 1 wherein all of said wires comprise copper.

5. The cable of claim 4 wherein said layers alternate in direction of lay.

* * * * *

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,760,093

Dated September 18, 1973

Inventor(s) Denver L. Pemberton

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 3, line 6; cancel "or" and insert --of--.
line 23; cancel "wire", second occurrence, and
insert --wires--.

line 51; cancel "unildy" and insert --unilay--.

Column 4, line 60; cancel "round" second occurrence.

Column 6, line 14; cancel "10.56" and insert --1.056--.

Claims 2,3,4, and 5; line 1, cancel "cable" and insert
--conductor--.

Signed and sealed this 12th day of February 1974.

(SEAL)

Attest:

EDWARD M. FLETCHER, JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents

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