

United States Patent

Lombardi et al.

[15] 3,686,428

[45] Aug. 22, 1972

[54] **MULTIPLE STRAND CONDUCTOR
WITH INCREASED CONTACT
RESISTANCE**

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[22] Filed: **Oct. 26, 1971**

[21] Appl. No.: **192,240**

[30] **Foreign Application Priority Data**

Oct. 29, 1970 Italy.....89560 A/70

[52] U.S. Cl.**174/128**, 29/191.6, 117/230,
174/119 C, 174/126 CP, 174/130

[51] Int. Cl.**H01b 5/10**

[58] Field of Search....174/126 C, 126 CP, 128, 131
A, 174/131 R, 130, 119 C, 108; 117/230, 231;
29/191.6

[56]

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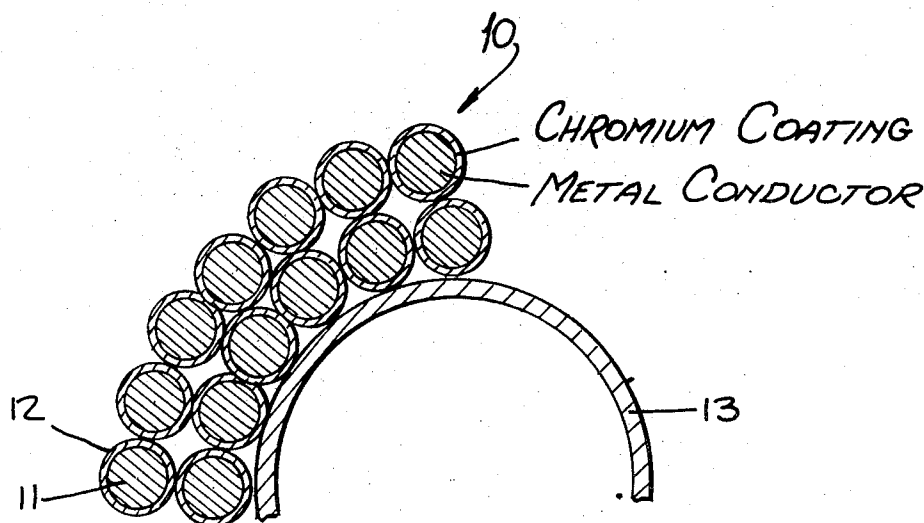
Attorney—Lorimer P. Brooks et al.

[57]

ABSTRACT

A conductor of stranded copper wires having a coating of chromium or chromium-based metal between the contacting surfaces of all or a portion of such wires to increase the contact resistance thereof. Also, a cable having a plurality of layers of such wires with such a coating between at least a pair of layers.

10 Claims, 2 Drawing Figures



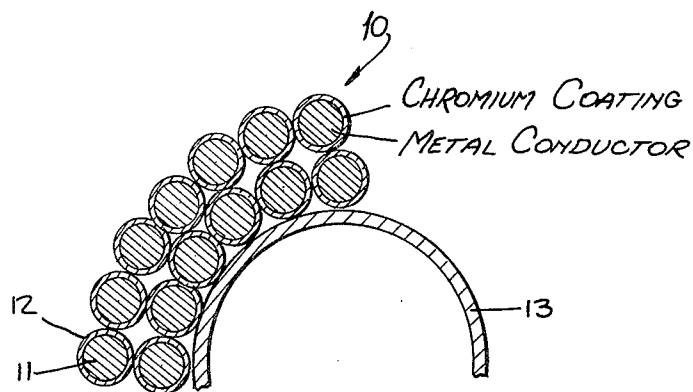


Fig. 1.

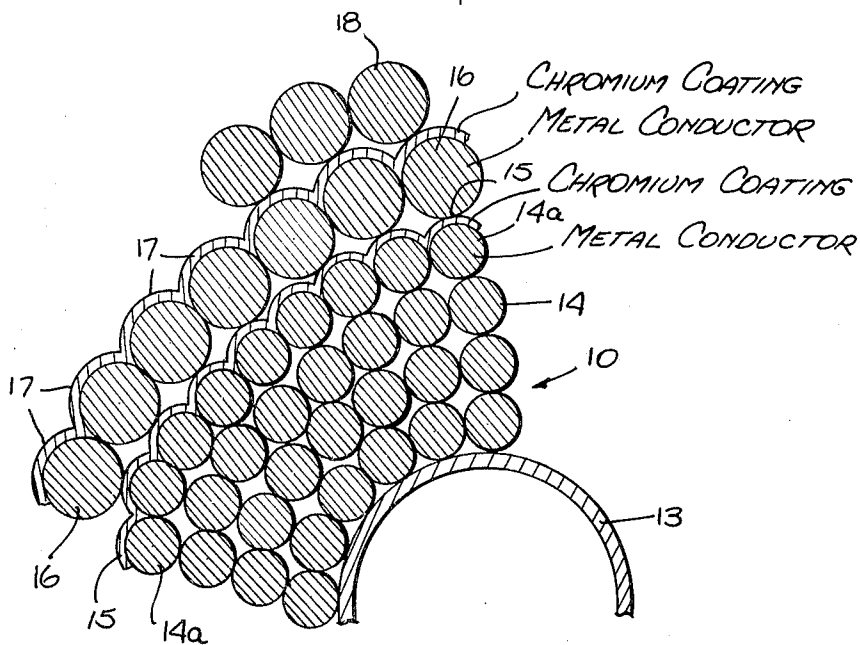


Fig. 2.

MULTIPLE STRAND CONDUCTOR WITH INCREASED CONTACT RESISTANCE

The present invention refers to electric conductors, in particular, conductors for alternating current, oil-filled power cables, and to the process for their manufacture.

The ever increasing trend to the use of large-size electric conductors for alternating current power cables in order to increase the transmitted power is well known. On the other hand, it is also known that there are serious drawbacks in the use of said conductors, due to the skin effect and to the proximity effect, which, raising the actual resistance of the conductor, often offset any advantage deriving from the increase of the conductor size.

To minimize such effects, use is generally made of a Milliken-type cable, consisting, as known, of four or more sector-shaped conductive elements, stranded separately, arranged in such a way as to form a core conductor of circular section. Each sector is generally constituted by copper wires stranded together.

This arrangement proves advantageous in counterbalancing the skin effect and the proximity effect, since it approximately balances the drop of inductive voltage in each wire. However, it is necessary to take into account the fact that, when there is a passage of current from one wire to the other, the efficiency of said arrangement is considerably reduced. It is therefore of great importance to obtain conductive elements of this type so constituted that the passage of current from one wire to the other is reduced to a minimum.

In order to obtain a high contact resistance between adjacent conductive wires, it is necessary to provide the wires with a covering of an appropriate material which will provide a contact resistance higher than that of the bare wire. This involves several problems, since first of all it is necessary to choose a material which does not dissolve in the fluid oil used to impregnate the cable which, in any event, does not give rise to drawbacks when it comes into contact with said oil.

Secondly, the material covering the wires must be easily removed by simple clamping when cables of this kind are joined, and at the same time must remain unaffected during handling and stranding of the wires.

It is known that a higher contact resistance covering of the conductive wires can be obtained by applying thereto a thin aluminum film. However, the application of said covering involves difficulties, requiring sometimes the adoption of a complicated and expensive process and equipment, both when using the method of spraying aluminum particles and when hot dipping or friction methods are employed.

It has now been found that it is possible to provide a conductive element constituted by several stranded metal wires which are, relatively speaking, insulated from one another by means of a film which, on one hand, possesses a high contact resistance and, on the other hand, is able to solve all the problems concerning both its application and its performance under service.

Accordingly, the object of the present invention is a conductive element comprising conductive metal wires stranded together and provided with a film or coating which, as regards the passage of current from one conductive metal wire to another one, has a contact resistance higher than the longitudinal resistance of said conductive metal wires, such film being a chromium-

based film. Preferably, the film is constituted by a plating of chromium in the state of metal which, as is known, passivates rapidly when exposed to air.

The thickness of the film preferably is in the range of from 1 to 20 microns. Within this range the plating has the insulating characteristics required for the objects of the invention at least without having such a brittleness as to cause its detachment during handling, particularly when stranding the conductive wires.

The film according to the present invention can either completely cover the individual metal wires constituting the cable sector, being applied on them before their stranding, or can cover several metal wires already stranded together, being applied to the strand constituting said sector in such a way as to cover the radially outer surface of the core strand and then, successively, the radially outer surfaces of each layer of wires which is subsequently stranded on said core strand.

The metal wires which are provided with said insulating film are preferably made of copper.

As usually made, in order to form a Milliken cable, a number of sectors constituted as set forth above, is then insulated with paper or with any other appropriate material, and said sectors are finally joined together so as to form a large conductor or cable having a circular cross section.

A further object of the present invention is a process for the formation of said film, which consists in electrolytically depositing chromium obtained from a solution containing chromium salts, already known per se, on the conductive metal wires.

These and other objects of the invention will be apparent from the following detailed description of preferred embodiments of the invention, which description should be considered in conjunction with the accompanying drawing in which:

FIG. 1 is a cross-sectional, end view of a cable sector formed from stranded wires individually coated in accordance with the invention; and

FIG. 2 is a cross-sectional, end view of a cable sector formed from stranded wires with additional wires overlying the cable sector and with the radially outward surfaces of the sector and the overlying wires coated in accordance with the invention.

The cable sector 10 shown in FIG. 1 comprises a plurality of stranded wires 11, preferably made of copper, which are provided on their surfaces with a coating 12 of chromium. The coating 12 is exaggerated in thickness for purposes of illustration, and only one cable sector 10 is shown, it being understood that three additional sectors surround the hollow central duct 13 which may, for example, be a steel coil.

An alternative embodiment of the invention is illustrated in FIG. 2, which also shows a sector 10 of a cable having a hollow central duct 13. The sector 10 comprises a plurality of stranded wires 14, preferably of copper, and the radially outward surfaces of the outer wires 14a of the sector 10 are coated by a coating 15 of chromium.

The cable sectors are surrounded by a plurality of wires 16, also preferably of copper, which are coated on their radially outward surfaces with a coating 17 of chromium. Further layers of wires 18 overlie the layer of wires 16, and if further wire layers are to overlie the

layer of wires 18, the radially outward surfaces of the wires 18 may be similarly coated with a coating of chromium.

With the embodiment of FIG. 1 the individual wires 11 have relatively high resistivity paths therebetween, whereas in the embodiment shown in FIG. 2, there are relatively high resistivity paths between the sector 10 and the overlying layer of wires 16. Similarly, there are relatively high resistivity paths between the layer of wires 16 and the layer of wires 18.

The films or coatings 12, 15 and 17, have a relatively high contact resistance, and this has been demonstrated by analytical laboratory tests carried out on copper wires so covered in comparison with copper or aluminum wires devoid of any covering layer.

The tests have been effected as follows:

Two copper wires, approximately 2.8 mm in diameter and covered with a 2 micron thick chromium film, are placed on a 4 cm wide, 5 cm long and 1 cm thick conductive copper plate. Said wires, having a length greater than that of the plate, are arranged on it in rectilinear shape, parallel to one another, symmetrical with respect to the plate midline and at a mutual distance of 2.5 cm so that, while one edge of the plate coincides, for both wires, with one of their ends, the other end of the wires project beyond the opposite plate edge.

Then, a second plate having the same size as the first and made of insulating material is positioned on the wires and is subjected to a load of 100 kg, so that each wire length of 1 cm is loaded with 10 kg. The two wires are connected, at their free end, to a current generator, and a current equal to 0.3-1 amperes/mm² is passed therethrough.

The potential drop between the two wires is measured at the projecting portions of the wires where they project from the plate edge. In this way a voltage value is obtained, the knowledge of which, together with the intensity of current conveyed in the circuit, the actual resistivity of the copper wire, namely of the metal wire irrespective of its covering, and the geometrical configuration of the system, permits one to obtain by calculation the value of the contact resistance of the chromium coated wire, expressed as micro-ohms per meter of wire. Analogous tests have been carried out on uncovered copper and aluminum wires.

The results of the tests are as follows:

Wires	Density of test current (Amperes/mm ²)	Load on Wire (Kg/cm)	Contact resistance (Micro-ohms/	Contact resistance referred to bare copper
(Average				
			meter)	values)
Bare copper	0.3-1	10	3.5-4	1
Aluminum	0.3-0.7	10	25-35	8
Chromium-plated				

copper 0.3-1 10 50-70 16

From these results it is evident that the chromium-plated copper wires have a considerable contact resistance which is, by far, higher than that shown by the aluminum wire.

It is understood that the present invention is not limited to the preferred embodiments described above, and alternative embodiments embodying the principles of the invention will be apparent to those skilled in the art.

What is claimed is:

1. A conductor comprising a plurality of metal wires in contact with each other, at least one of each of the two contacting wires having a coating thereon and between it and the other wire, said coating being selected from the group consisting of chromium and chromium-based metals and the metal of the coated wires being different from that of said coating, thereby to provide a contact resistance between said wires which is higher than the longitudinal resistance of the wire.

2. A conductor as set forth in claim 1, wherein said coating has a thickness in the range from 1 to 20 microns.

3. A conductor as set forth in claim 1, wherein said coating is passivated chromium.

4. A conductor as set forth in claim 1, wherein each of said wires is surrounded by said coating.

5. A conductor as set forth in claim 1, wherein the metal of said wires is copper.

6. A conductor as set forth in claim 1, wherein said wires are arranged in a plurality of layers around a central axis and said coating is between the radially outer surfaces of one wire layer and the adjacent surfaces of the wires of the next radially outward layer.

7. A conductor as set forth in claim 6, wherein said coating is between each of a plurality of said layers.

8. An alternating current cable having a core comprising a plurality of stranded wires extending around the axis of said core and at least one layer of stranded wires surrounding and contacting the wires of said core, at least a plurality of said wires having a coating thereon at least between such last-mentioned wires and the next adjacent wires, said coating being selected from the group consisting of chromium and chromium-based metals and the metal of the coated wires being different from that of the coating.

9. A cable as set forth in claim 8, wherein said coating is on the radially outward surfaces of the outer wires of said core and between the latter and said layer of wires.

10. A cable as set forth in claim 8, wherein said wires are made of copper, said coating is chromium-plated thereon and said coating has a thickness in the range from 1 to 20 microns.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,686,428

Dated August 22, 1972

Inventor(s) Aurelio Lombardi, Pietro Anelli, Gianfranco Bianchi

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

On the front page beside identifier [73], "Phirelli" should be --Pirelli--. Column 1, line 40, "doe" should be --does--. Column 1, line 57, "one", first occurrence, should be --on--. Column 3, in the table at the bottom thereof:

line 6, first column, strike "(Average"
line 6, fourth column, insert --meter)--
line 6, fifth column, insert --(Average values)--
Strike line 7
line 11, first column, after "plated" insert --copper--
line 11, second column, insert --0.3-1--
line 11, third column, insert --10--
line 11, fourth column, insert --50-70--
line 11, fifth column, insert --16--

Column 4, strike lines 1 and 2.

Signed and sealed this 17th day of April 1973.

(SEAL)
Attest:

EDWARD M. FLETCHER, JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents

UNITED STATES PATENT OFFICE
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