June 15, 1937. K. S. WYATT 2,083,889

OXIDATION RESISTANT CABLE

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Fig. 1.

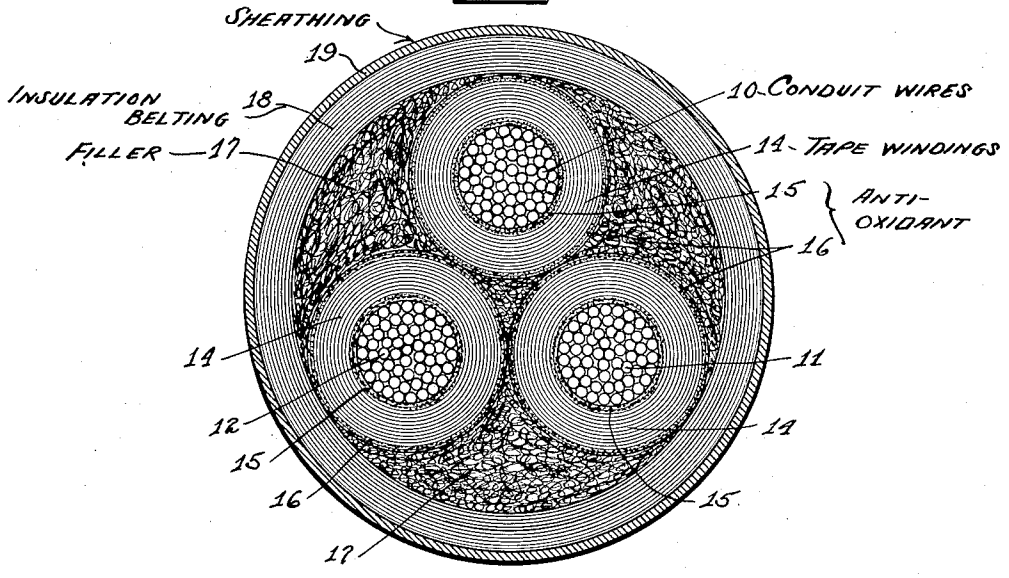
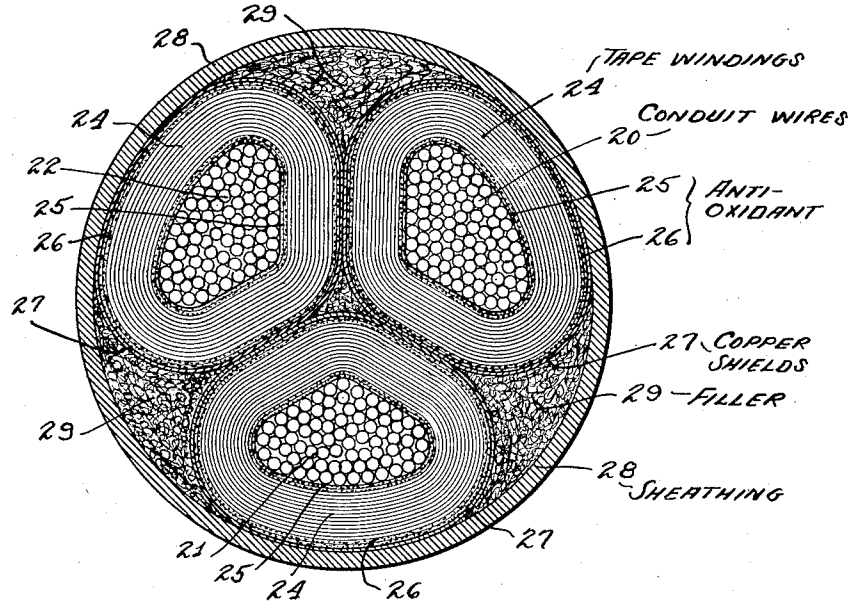


Fig. 2.



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OXIDATION RESISTANT CABLE

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13 Claims. (Cl. 173—266)

This invention relates to cables having anti-oxidant materials dispersed at strategic points in the insulation surrounding the conductors.

More specifically, this invention relates to impregnated paper insulated, lead sheathed cables having anti-oxidant material incorporated into or coated on the inner and outer windings of the paper insulation to prevent formation of oxidation products.

Paper insulated cables when placed in service have been found to suffer a gradual deterioration which is evidenced by increasing dielectric losses. The causes of this deterioration and the manner in which it progresses have not, heretofore, been understood.

I have now found that oxidation is a major cause of the deterioration of cable insulation and have provided means for the prevention of such oxidation.

My invention is particularly adapted for use in cables having impregnated paper insulating tape wound around the conductors. The paper insulation is generally impregnated with an insulating material such as a mineral oil. Each conductor is wound with a number of windings of the treated paper. Three of the so wound conductors are generally inserted in a sheath of belt insulation or are wrapped individually with copper shielding tape. The spaces between the conductors are filled with material such as jute or cellulose fibers. The entire cable is then enclosed within a lead sheath. This type of three-conductor cable is mostly used for underground current transmission, because of its low cost as compared with rubber or varnished cambric insulated cables. It has been considered to be inferior to the more expensive cables because of the deterioration discussed above, resulting in an increase in dielectric losses after usage. The application of my invention to such cables, however, so largely reduces the deterioration as to make the cables stable and efficient even after years of service.

In accordance with my invention, the inner windings of the impregnated paper tape surrounding the metal conductors are treated with anti-oxidant material which prevents any oxygen which may be present or developed within the cable or in the paper from reacting with the paper or materials with which the paper is impregnated to form oxidation products. In addition, I propose to treat the outer wrappings of the paper insulation with anti-oxidant material to prevent oxygen entering from the outside from reacting on the paper or impregnation materials.

It has been found that the oxidation products are largely hydrophils; that is, they will spread on water. One explanation for the harm done by the hydrophils is that any water which may seep into the cable will form a carrier for this type of oxidation product, and by spreading these products throughout the cable, greatly increase the losses present in the dielectric between the conductor and the sheath.

The oxidation products themselves have a lower dielectric strength than their unoxidized parent materials and reduce the insulation capacity, even though water does not seep into the cable. Both water and oxygen may reach the inner and outer layers of the paper insulation via the air or moisture in the paper or in the material with which the paper is impregnated at the time of manufacture, or because of air or moisture being drawn in at the time of insulation, or because air or moisture is breathed in at porous joints or at imperfections in the lead sheath during service, or by formation of air or moisture from an ionization action on the cellulose molecules of the paper.

It is, therefore, an object of this invention to provide a cable structure adapted to resist oxidation of any of its constituent elements.

Another object of this invention is to prevent the formation of oxidation products in insulating materials for cables.

Another object of this invention is to maintain the original dielectric strength of insulating materals in cables.

Another object of this invention is to maintain the power factor of the insulation materials used in cables uniform throughout their width.

Another object of this invention is to prevent the formation of hydrophils in impregnated paper insulation for conduits.

Other and further objects of this invention will be apparent to those skilled in the art from the annexed drawing and following description.

On the drawing:

Figure 1 is a vertical cross-sectional view of a three-conductor belted cable having impregnated paper insulation tapes which are treated with anti-oxidant material wrapped around each conductor.

Figure 2 is a vertical cross-sectional view of a three-conductor H-type of cable in which impregnated paper tapes surrounding each conductor are treated with anti-oxidant materials.

As shown on the drawing:

In Figure 1, the reference numerals 10, 11 and 12 indicate respectively the three sets of conduit

wires forming the three conductors for the cable. Each conductor 10, 11 and 12 is surrounded with a covering of oil impregnated paper tape 14.

The first few inner windings 15 of the paper tape 14 are treated with an anti-oxidant material, such as hydroquinone, camphor or any well-known anti-oxidant. The last few outer windings 16 of the paper tape 14 are treated in a similar manner. For example, if about 50 windings of the tape are placed around the conductor, the first ten and the last ten windings are treated with the anti-oxidant. Layers 10 to 40 are untreated. Thus only 40% of the tape is treated; 20% being on the inner windings and 20% on the outer windings.

A filler material 17 such as jute or cellulose fiber is packed around the outside of the paper tape 14 and the entire mass is wrapped in an insulation belting 18. A lead sheathing 19 forms the outside of the cable.

The cable described above is known to the trade as a three-conductor belted cable, since the filler material is wrapped with the belting 18.

In Figure 2, the reference numerals 20, 21 and 22, respectively, indicate the conduit wires forming the three conductors of the cable. Each conduit 20, 21 and 22 is surrounded by a covering comprising a plurality of layers of oil impregnated insulation paper 24. The inner windings 25 of paper insulation are treated with anti-oxidant material in accordance with this invention. Likewise, the outer windings 26 are also treated with an anti-oxidant material.

A copper shielding tape 27 is then wound around the paper insulations on each conductor and the three conductors are packed together in a lead sheathing 28. Filler material such as cellulose fibers 29 are provided to fill up the spaces between the insulated conduits and the outside lead sheath.

The cable shown in Fig. 2 is known as a three-conductor H-type cable. Both the cables shown in Figs. 1 and 2 are impregnated paper insulated, lead sheathed cables.

It should be understood that while only two specific types of cables have been described and shown in the drawing, nevertheless, my invention is applicable to any type of cable irrespective of the number of conductors therein. As will be obvious to those skilled in the art, the incorporation of anti-oxidants in insulations is applicable to any type of insulated cable or conduits.

My invention, therefore, comprises introducing anti-oxidant materials into the inner layers of insulation near the conductor and into the outer layers of insulation next to the lead sheath in single conductor cables or near the outer layer of each core in a multi-conductor cable. Where belted cables are used, it is sometimes desirable to introduce anti-oxidants into the inner and outer layers of the belt insulation.

I have found after considerable investigation of used cable that the oxidation products and hydrophils are formed in the inner and outer layers of the insulation tapes. The layers in the middle are, for the most part, unoxidized and these layers, in effect, maintain the dielectric strength that remains and prevent an increase in losses. By preventing oxidation of the inner and outer layers therefor the entire tape is protected.

In any particular case the number of inner and outer layers which will be treated with an anti-oxidant is dependent, to a large extent, on the amount of oxidation products formable from the particular grade of mineral oil, paper and filler used in building up the cable. I have found that the need for an anti-oxidant varies considerably with the quality of the cable dielectric materials.

The following table is presented to show the extreme range of percentages of oxidation products present in typical layers of the winding, and to show what might be termed the average percentage for normal cables after a period of use extending over many years:

No. of layers of paper from conductor	Extreme range of percentages of oxidation products present*	Aver. percentage of oxidation products
1	0.1 to 10	2.5
5	0.1 to 8	1.3
10	0.1 to 5	0.8
20	0.1 to 4	0.5
30	0.1 to 4	0.5
40	0.1 to 5	0.8
45	0.1 to 8	
50	0.1 to 10	2.5

*Determined by the water-spread method.

In general the stronger anti-oxidant can be applied in smaller quantities than the weaker anti-oxidants. This may be accomplished by reducing the number of layers which carry an anti-oxidant, or by decreasing the amount of anti-oxidants per layer. In practice it is found that the first 1 to 10 layers are all that need to be coated.

The anti-oxidant material may be introduced into the paper tape in any suitable manner. One satisfactory method is to soak the paper tape in a solution of the anti-oxidant, drying the so treated paper and using this tape for the inner and outer layers as the cable is built up.

While I have used the term "anti-oxidant" throughout this specification, it should be understood that I do not wish to be limited to anti-oxidants per se. My invention is also applicable to the use of inhibitors of oxidizing reactions, and to stabilizers of the chemical reactions which take place within the various dielectric substances during use of the cable.

Some of my experiments have been based on determinations of the dielectric strength of the solid and liquid substances present in the various layers of the dielectric as determined by the measurement of the power factor of various portions of the dielectric. I have found from these measurements that the power factor, in a used cable, is a maximum near the conductor and near the sheath, and reaches a minimum approximately midway between the two. By distributing anti-oxidants, stabilizers or inhibitors non-uniformly throughout the dielectric, as suggested above, I have found that it is possible to maintain the power factor of the dielectric substantially constant throughout the dielectric. This is, of course, extremely beneficial in that it enables the cable user to maintain the dielectric losses at a minimum throughout many years of cable operation.

Some of my experiments and the apparatus with which I determined the power factor are more fully described in a paper published in "Electrical Engineering" for July, 1933, page 450.

Examples of suitable materials which can be used to stabilize the cable dielectric are:

Aldehyde-amine condensation products, includ-

ing butyraldehyde-anilene derivatives and acetaldehyde-ethylenediamine condensation products.

Condensation products of aldehydes with alkylene diaryl diamines.

Naphthyl substituted benzidine compounds.

Aromatic compounds having a hydroxyl or amino group attached to the ring such as—

Pyrogallol
Diphenylamine
Gallic acid
Dibutylresorcinol
Beta naphthol
Hydroquinone
Phenyl-beta-naphthylamine
Aldol-alpha-naphthylamine
Alkylenediaryldiamines
Di-beta-naphthal-para-phenyldiamines, and
Camphor,
Tannin
Para-amido-phenol,
Tri-oxymethylene and glycerine.

Any material which prevents or reduces oxidation of cable insulation materials and which does not, itself, react with the insulation or conductor metal may be used. Thus, any anti-oxidant except those potent enough to react with the conductor wires or insulation materials, is desirable.

The anti-oxidant may be dissolved in a solvent such as water, benzol or other liquid which can be readily evaporated from the paper after impregnation. Any concentration of the anti-oxidant may be used. I have used solutions containing from 1 to 50 parts by weight of the anti-oxidant in 100 parts of solution.

Instead of soaking the insulation tapes in an anti-oxidant solution, the anti-oxidant may be prepared as a paste and applied to the surface of the conductor to contact tape wound thereabout.

Since some anti-oxidants may impair the electrical characteristics of the cable, it has been found that the placing of the anti-oxidant only on the inner and outer layers of the paper surrounding the conduit is more desirable than uniformly impregnating all of the paper insulation with anti-oxidant. Furthermore, the amount of anti-oxidant necessary is greatly reduced by our proposed unequal distribution in the paper insulation.

Various amounts of anti-oxidant materials may be used, since each anti-oxidant material may have a different strength. I have found in the use of hydroquinone, that for the inner layers of the paper insulation, about 2.4% of hydroquinone based on the weight of the dry paper is sufficient. This is about 3.3% of hydroquinone based on the weight of oil in the paper. The outer layers may contain lesser amounts and 2% of hydroquinone based on the weight of oil is sufficient for these layers or 1.4% based on the weight of the dry paper.

The above percentages of hydroquinone apply to a cable in which the oxidation products are present in the amounts given in the third column of the table on page 6, and the amounts of hydroquinone are based upon the addition of sufficient hydroquinone to neutralize the oxidation products in the first 10 layers of the tape next to the conductor, and in the last ten layers of the tape next to the sheath.

While the above description has been confined to the non-uniform distribution of anti-oxidants or stabilizers in oil impregnated paper insulations for cables, it should be understood that this non-uniform distribution or dispersion is applicable to any dielectric material. My invention is therefore, not limited to the non-uniform distribution of anti-oxidants in paper insulation tapes.

Having now described my invention, I claim:

1. An electrical cable comprising an electrical conductor, layers of insulation material surrounding said conductor, an anti-oxidant compound dispersed throughout inner and outer layers of said insulation material only and an outside covering for said cable.

2. In an insulated electrical cable, impregnated paper tape insulation having anti-oxidant material concentrated in the inner and outer windings thereof.

3. An insulated cable comprising conductors for electrical current, insulation tape wound around said conductors having anti-oxidant material concentrated in the inner windings thereof and a covering for said cable.

4. An electrical cable comprising conductors for electrical current, insulation tape wound around said conductors having anti-oxidant material therein concentrated in the inner and outer layers thereof and a covering for said cable.

5. An oxidation resistant electrical cable comprising electrical conductors, insulation tape wound around said conductors having anti-oxidant material impregnated into the first few windings and into the last few windings only, and a covering for said cable.

6. An oxidation resistant electrical cable comprising conductors for electrical current, tape insulation wound around each conductor having hydroquinone dispersed throughout the inner and outer windings thereof and a sheathing for said cable.

7. An oxidation resistant electrical cable comprising conductors for electrical current, paper insulation wound around each conductor having phenyl-beta-naphthylamine dispersed therein and concentrated throughout the inner and outer windings thereof, and a sheathing for said cable.

8. An oxidation resistant electrical cable comprising conductors for electrical current, a paste of anti-oxidant material surrounding said conductors, insulation wrapped over said paste to concentrate the paste around the conductors and a sheathing for said cable.

9. An oxidation resistant electrical cable comprising conductors for electrical current, impregnated paper insulation wound around each conductor having an anti-oxidant material localized in the inner and outer windings, an insulation belting having an anti-oxidant material dispersed in its inner and outer windings wrapped around said insulated conductors and a lead sheathing for said cable.

10. An oxidation resistant cable comprising conductors for electrical current, oil impregnated paper insulation wound around each of said conductors, the inner windings of said paper having localized therein an amount of anti-oxidant equivalent to about 2.4% of hydroquinone based on the weight of the dry paper, while the outer windings have localized therein an anti-oxidant equivalent of 1.4% of hydroquinone based on the weight of the dry paper.

11. In an insulated electrical cable, a conductor for electric current, layers of insulation material surrounding said conductor and anti-oxidant material concentrated in the inner and outer layers of said insulation.

12. In a conductor for electric current, layers of insulation material surrounding the electrical conductor and anti-oxidant material concentrated in the inner and outer layers of said insulation material.

13. In a conductor for electric current, layers of porous insulation material surrounding the electrical conductor having anti-oxidant material concentrated in the layers adjacent to the conductor.

KENNETH S. WYATT.