

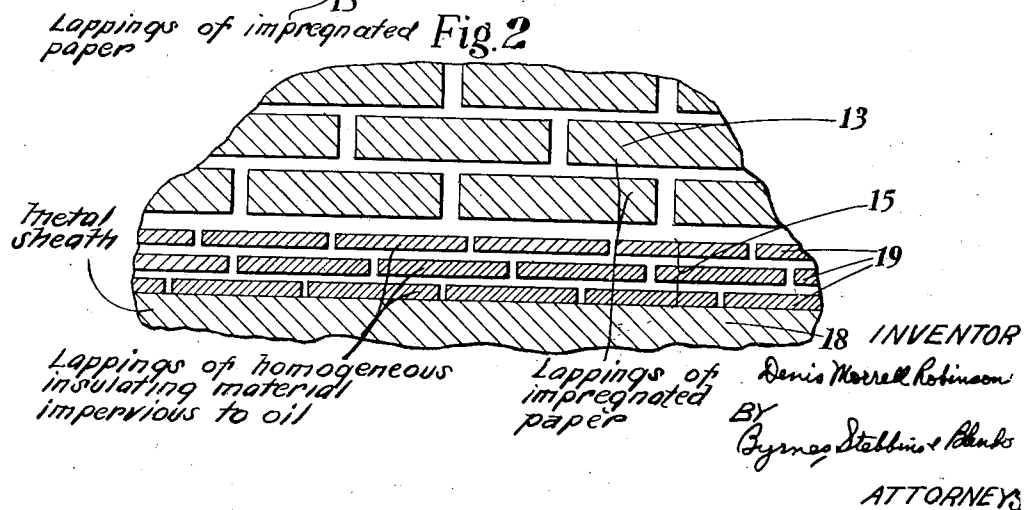
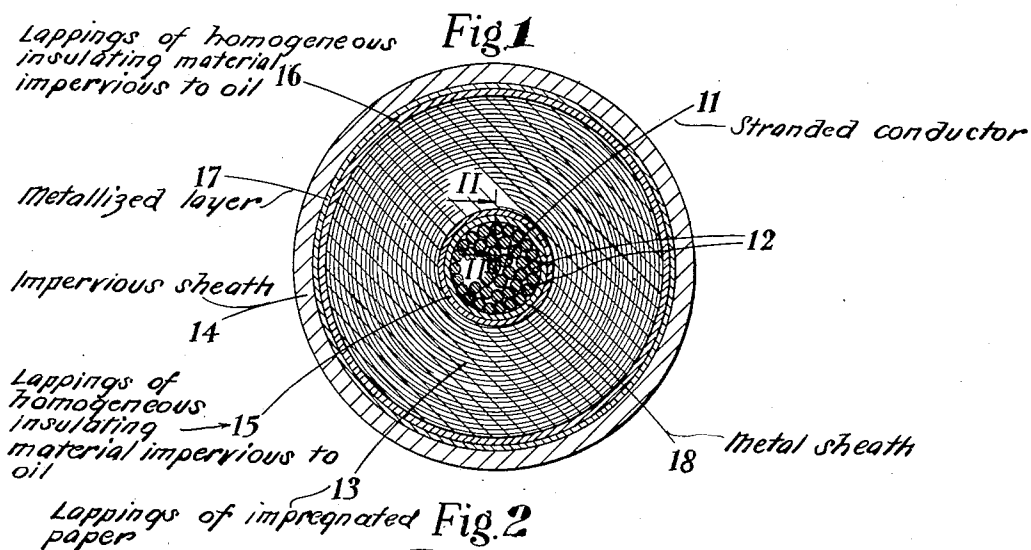
Dec. 21, 1937.

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2,102,974

ELECTRIC CABLE

Filed June 12, 1935



UNITED STATES PATENT OFFICE

2,102,974

ELECTRIC CABLE

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Application June 12, 1935, Serial No. 26,135
In Great Britain June 22, 1934

2 Claims. (Cl. 173—266)

The invention relates to high tension electric cables of the kind in which the dielectric is formed of laminated and impregnated material, usually paper impregnated with oil or compound (hereinafter for convenience referred to as compound). Cables of this type, whether the solid part of the dielectric consists of paper or other fibrous material, will hereinafter be termed, for convenience, impregnated paper insulated cables.

In cables of this kind there may be present in the part of the cable subjected to electrical stress, small gaseous or vacuous spaces, usually termed voids. These voids may be due to incomplete impregnation of the body of insulation but more usually they are caused by subsequent migration of the impregnating medium in a radial and/or longitudinal direction due, for instance, to the thermal cycle which the cable undergoes during its working life or to drainage.

It has generally been assumed that such voids usually constitute the initial cause of breakdown of the cable. Various proposals have been made for inhibiting, or reducing the probability of, the formation of such voids. For instance, it has been proposed to prevent the production of voids during the cooling part of a cycle by facilitating return flow of the impregnating medium into the body of fibrous dielectric by means of oil ducts and/or maintaining the interior of the cable under a pressure greater than atmospheric. Cables in which return flow of the compound is so facilitated have proved to be satisfactory from an electrical point of view but unfortunately necessitate the use in conjunction therewith of expensive auxiliary plant. In British Patent No. 175,753, it has been proposed to prevent migration by enclosing the insulation by means of thin separating layers of a non-metallic material which is impervious to the compound with which the fibrous dielectric is impregnated. One of these layers encloses the conductor in order to prevent the flow of compound into the interstices of the conductor and the production of voids during the cooling part of a cycle due to the disinclination of the compound to flow back from the interstices into the fibrous insulation. These precautions may result in the inhibition of the production of voids within the dielectric body, but this inhibition is not, for reasons to be explained later, sufficient to make the cable resistant to breakdown. In British Patent No. 407,718 there is described a construction of high tension cable in which it is intended that voids should be non-existent. In this case the use of impregnated paper insulation is abandoned in

favour of a dielectric consisting wholly of a water resistant thermoplastic compound applied in layers by extrusion. Insulation of this kind is at present relatively expensive as compared with impregnated paper insulation. Moreover such a cable would not possess the degree of flexibility possessed by a paper insulated cable due to its insulation being built up of successive layers that are free to slide over one another and are formed of helical lappings of tape.

The problem before the manufacturer of super-tension cable is therefore to produce an impregnated paper insulated cable which is resistant to breakdown under working conditions but does not necessitate the use in conjunction therewith of expensive auxiliary plant. With this in view the applicant has conducted extensive researches as a result of which he discovered that the breakdown of the dielectric of impregnated paper insulated cables is in the great majority of cases initiated at or close to the conductor in spaces containing gas and having the conductor as the inner boundary and the dielectric as the outer boundary.

The starting of the process which results in breakdown is usually due to the bombardment of the outer boundary surface of such a space by ions liberated from the gas in the space and propelled by the electric force in the space. This bombardment causes carbonization either of the compound or of the paper. It is found that the carbonization of the compound can proceed within and through the paper, owing to the fact that paper is not homogeneous. The paper is made up of fibres felted together and containing or enclosing cells or passages which are made to contain compound as the result of the impregnating process. Carbonization can proceed along threads of compound extending through these passages.

In the light of this discovery it appears, contrary to the opinion hitherto held by cable manufacturers, that the object to be aimed at is the elimination of possible gas spaces bounded by the surface of the conductor rather than the elimination of possible gas spaces within the body of insulation constituting the dielectric. This statement does not imply that the presence of voids within the insulation is not undesirable but that the existence of such voids is not so conducive to breakdown as is that of voids between the surface of the conductor and the insulation.

These researches suggest that the problem set out above may be solved by interposing between the surface of the conductor and the innermost

layer of the impregnated body of dielectric, a thin but continuous layer that is in complete contact with the conductor throughout the inner surface of the layer and is formed of a homogeneous insulating material impervious to oil or compound.

For the purposes of this specification the term homogeneous insulating material implies an insulating material which is not built up of fibres that retain their individuality and which does not contain small voids, cracks or microscopic channels such as are present in paper.

Materials which are regarded as sufficiently homogeneous for the present purpose and are mentioned by way of example are found amongst the following:—esterified cellulose compositions, such as those having a cellulose acetate basis; cellulose ethers such as benzyl cellulose; polystyrenes, for instance styrol; and oil-resisting rubber-like compounds, for instance, the olefine polysulphide compounds sold under the trade name "Thiokol".

From my researches it appears that the continuity of the covering must be such that there is no passage in a radial direction through the layer, but I have found that it is permissible to build up the layer of thin helical strips of material applied with a substantial overlap, providing that where gaps exist between the adjacent surfaces of the conductor and of the layer these are reduced to a very small value, say not exceeding 2 mils (0.05 mm.) in radial measurement.

The present invention accordingly comprises a novel construction of paper insulated cable embodying in a practical manner the results of my researches. The improved cable comprises a conductor of which the surface is made smooth and of non-reentrant configuration and, interposed between the conductor and the innermost layer of the surrounding body of impregnated paper insulation, a comparatively thin (that is thin in comparison with the surrounding body of insulation) continuous layer, of homogeneous insulating material impervious to oil or compound. This layer is formed by helically lapping the conductor with one or more strips of such material, the thickness of the strips being not more than 2 mils (0.05 mm.). The use of such a conductor in combination with the impermeable layer built up of strip of these dimensions ensures that gaps between the adjacent surfaces of the conductor and of the layer do not exceed 2 mils in radial thickness.

In order to provide a margin of safety it will generally be advisable to form the layer of homogeneous material of several superposed layers of strip. For instance where each strip is applied with a small gap between its successive turns, six strips may be used to build the homogeneous layer.

Smoothering the surface of the conductor may be effected by building it, or the outer part of it, from wires of a section appropriate to give a continuous cylindrical form. Alternatively, a strand formed of round wires may be covered by a sheath of metal, for instance of lead, extruded over it, or by a metal tape or a metallized paper tape lapped tightly over it so as to cover the entire surface. In another form of construction, the innermost strip of the layer may have a metallized inner surface and be applied with a substantial overlap. The metallized surface of the strip makes contact with the conductor and thereby extends the surface of the latter to the

place where the metallized layer joins the homogeneous material on which it is carried.

In the accompanying drawing, which shows an example of construction of high tension impregnated paper insulated cable according to the invention,

Figure 1 is a cross-sectional view of the cable, and

Figure 2 is a fragmental sectional elevation, on a greatly enlarged scale in a radial direction, taken on the line II—II in Figure 1, of the cable shown therein.

In the construction of the cable shown in Figures 1 and 2, the conductor 11, consisting of a plurality of wire strands 12, is insulated by a thick body of impregnated paper insulation 13 and enclosed within a lead sheath 14. A smooth surface of non-reentrant configuration is imparted to the conductor by covering it with a continuous sheath of metal 18 in contact with some or all of the outer wires of the conductor. On this smooth surface is applied the layer 15 of homogeneous insulating material. This layer is built up of overlapping turns of strip 19 of which the thickness is less than 2 mils (0.05 mm.). These strips 19 may be 1 inch wide and applied with a gap of $\frac{1}{16}$ inch between adjacent turns of the same layer. Each turn of a succeeding layer is arranged to overlap by a substantial amount two adjacent turns of the underlying layer. The overlap may, for instance, be 50:50, as shown in the case of the first and second layers or 75:25 as shown in case of the second and third layers. It will be appreciated that for the sake of clearness in Figure 2 the tapes are shown spaced apart in a radial direction and that they and the sheath 18 are drawn to a scale in a radial direction which is 60 to 70 times the scale in the longitudinal direction.

The outer part of the dielectric, that is to say the part beyond the layer covering the conductor, consisting of impregnating paper or equivalent material, may be applied and treated in the usual manner.

A cable constructed in accordance with the present invention is strengthened in the region where breakdown is likely to be initiated, and accordingly makes a close approach to complete immunity from failure of the dielectric under ordinary working conditions.

This strengthening may permit an appreciably higher electric stress to be used in the dielectric, and this may be carried to such a point that the effect, which previously was confined to the conductor, is made evident also at the sheath. In such conditions, steps analogous to those set out in the preceding description can be applied in accordance with the present invention to the region between the outer part of the dielectric and the sheath. It might, for instance, be carried out as shown in the drawing by applying, between the usual metallized layer 17 on the outside of the dielectric and the dielectric, a covering 16 which is of the same kind and has the same relation to the metallized layer as the covering hereinbefore described in connection with the conductor.

What I claim as my invention is:—

1. An impregnated paper insulated cable comprising a conductor having a smooth surface of non-reentrant configuration, a comparatively thin continuous covering of homogeneous insulating material impervious to oil and compound, surrounding said conductor and in contact therewith, said covering comprising at least

one lapping of strip, the thickness of which strip is not greater than two mils, an impregnated body of paper insulation surrounding said covering, and an impervious sheath enclosing the said body of paper insulation.

2. An impregnated paper insulated cable comprising a conductor having a smooth surface of non-reentrant configuration, a comparatively thin continuous covering of homogeneous insulating material impervious to oil and compound surrounding said conductor and in contact there-

with, said covering comprising a plurality of lappings of strip-like material, the thickness of the lapping of strip-like material being not greater than two mils, the adjacent edges of said lappings being spaced apart a predetermined distance and each layer substantially overlying its underlying layer, an impregnating body of paper insulation surrounding said covering, and an impervious sheathing enclosing the said body of paper insulation.

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