June 9, 1942. C. J. BEAVER ET AL 2,286,052

ELECTRIC CABLE

Filed Feb. 15, 1940 2 Sheets-Sheet 1

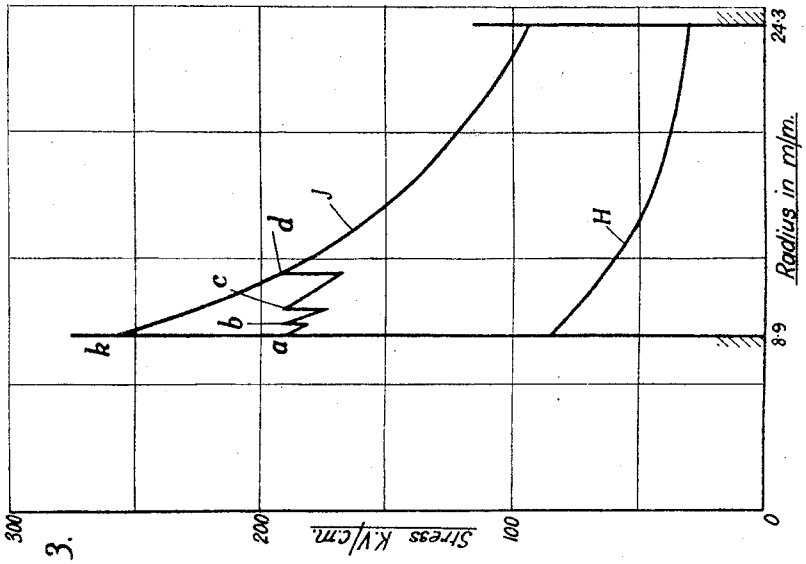


Fig. 3.

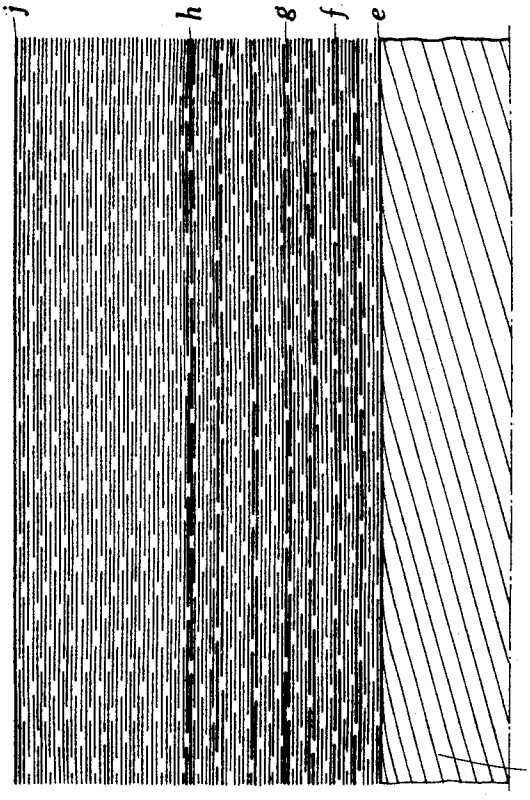


Fig. 1.

Inventor
Charles James Beaver
Edward Leslie Davey
by
Stibbins Blanksot Parmelee
Attorney

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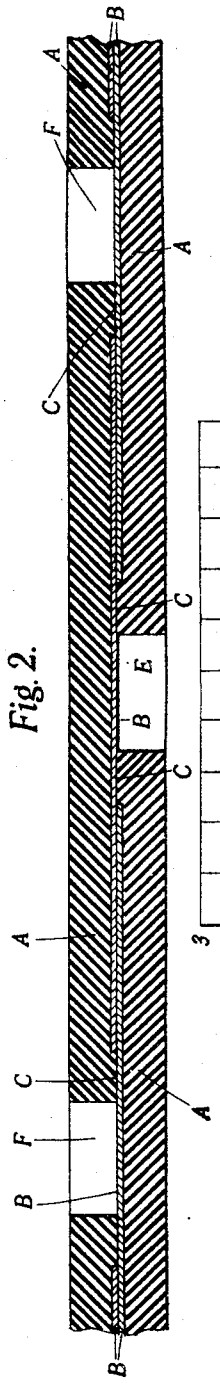


Fig. 2.

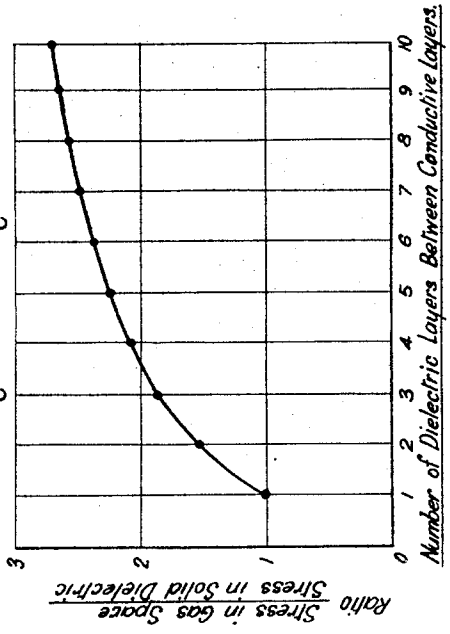


Fig. 4.

Inventor
Charles James Beaver
Edward Leslie Davey
by
Stevens Blenkarn & Parmelee
Attorney

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UNITED STATES PATENT OFFICE

2,286,052

ELECTRIC CABLE

Charles James Beaver, Bowdon, and Edward Leslie Davey, Timperley, England, assignors to W. T. Glover & Company Limited, Manchester, England, a British company

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In Great Britain February 28, 1939

6 Claims. (Cl. 174—25)

With the object of producing an improved dielectric for an electric cable by controlling the distribution of the potential therein, it has been proposed to place at one or more radial distances between the conductor and the outside of the dielectric a conductive layer concentric with the conductor. The present invention provides an improved form of such a layer and also a particular grouping of such layers which is adapted to be applied in a laminated dielectric built up of lapped strips of paper, or other material, applied helically in superposed layers.

In accordance with the invention a conductive layer is provided by utilising a particular form of metallised strips of paper, or other material, and applying these strips in a particular way. Metallisation is carried out in such a way that the conducting material is narrower than the strip of dielectric material and covers the central part only, leaving at each side a bare portion. Two of these metallised strips are associated together to produce a conductive layer. The first strip is lapped on helically so as to leave only a small space between the edges of adjacent turns. This material has the metallised surface placed outwards. Another strip is then applied directly over the first strip and with the metallised surface inwards so as to make contact with the metallised surface of the inner strip. The turns of the outer strip are so placed that they cover the small spaces between the turns of the inner strip and extend on either side thereof. In this way the two layers of metallisation make a complete conductive layer, which has the feature that at no place does an edge of the conducting material project into, nor is it exposed in, the spaces between adjacent turns. The presence of such an exposed edge would have the effect of producing a substantial disturbance in the distribution of the potential.

The improved form of conductive layer is particularly applicable to cables having impregnated paper dielectric with the spaces between the turns and layers of paper free of impregnating compound and containing gas at an appropriate pressure. Such cables are described in the specifications of Patents No. 2,067,169 and 2,067,170.

In providing a number of spaced conductive layers between the conductor and the sheath, each layer is caused by inductive action to have a potential in a definite relationship to the others, and change of stress in the gas spaces, in passing from point to point radially through the dielectric, may be controlled by the spacing of the conductive layers, provided that they have the freedom from local variation of potential which is given by the improved construction of layer hereinbefore described. By applying a comparatively small number of the improved conductive layers at appropriate positions in the region of maximum gradient in the dielectric of the kind above mentioned of high tension cable, the distribution of the potential within the dielectric can be so controlled that a sufficiently close approximation to a radially uniform gradient in the gas filled spaces is obtained in the region where this stress is highest. The gradient in the solid part of the dielectric is not materially changed by the presence and the spacing of the conductive layers but the ratio of the voltage gradient in the gas spaces to the voltage gradient in the solid material is affected thereby, being reduced as the spacing of the conductive layers is reduced.

In describing the invention further, reference will be made to the accompanying drawings. In these drawings Figure 1 represents diagrammatically the central longitudinal section of one half of a conductor and dielectric for a cable in which the invention is embodied. Figure 2 shows on an enlarged scale the construction of a conductive layer. Figure 3 shows the stress distribution in the cable illustrated in Figure 1 and Figure 4 shows a curve referred to in connection with Figure 3.

From Figure 2 it will be seen that each conductive layer is formed of two layers of paper, in each of which the paper strip A is metallised on one face so that the metallic surface B covers the whole of that face of the strip with the exception of a small portion C along each edge of the surface. The inner strip is lapped on helically over the next paper layer, leaving only a small space E between adjacent turns. The metallised surface B of this strip is placed outwards. The outer strip is then lapped on helically over the inner strip with its metallised surface B on the inside so as to make contact with the corresponding surface of the inner strip. The turns of the outer strip are so placed that they cover the space E between the turns of the inner strip and extend on either side thereof to the neighborhood of the centre line of the inner strip leaving only small spaces F between their edges. The two layers of metallisation B thus make a complete conductive layer without exposing in either of the spaces E or F an edge of the conducting material. In this very simple way a complete cylindrical conductive layer is provided.

It can be placed at any desired position within the laminated dielectric.

In Figure 1 an example of the location of the conductive layers in the dielectric, in accordance with the invention, is shown. In this figure the section through the two metallised papers of each conductive layer is shown by a set of horizontal overlying heavy lines. The layers of impregnated paper without metallisation are shown by light lines.

The metallised papers are impregnated in the same way and with the same material as the other papers so that the dielectric properties of all the papers are similar. The impregnation is carried out before the papers are lapped on the conductor and while the impregnating material is hot and this material is retained by the paper owing to its setting point being a temperature above those reached in the operating conditions of the cable. This procedure of impregnating before lapping results in the gas spaces being free of impregnating compound and has the further advantage, in the present case (as compared with the more usual procedure of impregnating after lapping) that it is unnecessary to perforate the metallised paper, thus permitting the obtaining of a completely unbroken conductive layer.

The stranded conductor G has applied to it first a smoothing layer of conductive material, indicated by the heavy horizontal line marked *e*. This may be a wrapping of conductive tape or may be a thin lead sheath. If the conductor is a solid rod no smoothing layer is, of course, necessary. The dielectric is bounded at the outside by a conductive layer indicated by the heavy horizontal line marked *j*. This will usually be a wrapping of conductive tape of well-known kind. The outer part of the dielectric between the layers *h* and *j* consists of wrappings of paper without metallisation. At the point *h* a conductive layer of the kind indicated in Figure 2 is inserted and between this point and the point *e* six other such conductive layers are shown, these layers being placed more closely together near *e* than near *h*.

In the example illustrated the conductor radius at the smoothing layer *e* is taken to be .35 inch (.89 m/m.) and the radius at the outer boundary *j* of the dielectric is taken to be .96 inch (24.3 m/m.). The distribution of the dielectric stress in this cable will now be discussed with reference to Figures 3 and 4. (The dielectric stress is numerically equal to the potential gradient in kilovolts per centimetre and will for convenience be referred to as "stress" in the following discussion.)

In Figure 3 the lower curve H is the stress calculated for the impregnated paper assumed to be homogeneous and to have a permittivity (dielectric constant) with the value of 3.3. The upper unbroken curve J shows the stress in the gas spaces between the turns and layers of paper for the usual case in which no conductive layers are inserted, the ordinates in this curve being three times those of curve H. By the insertion of conductive layers the value of this ratio can be reduced in the regions between the layers. The value to be used for such regions is shown in Figure 4 for different numbers of dielectric layers between conductive layers from 1 to 10. In designing such a spacing it must be remembered that the paper on which each metallised layer is applied has to be reckoned as one of the layers of paper between the conducting layers. Accordingly, a spacing of five paper layers would consist of the two layers supporting metallisation and thre unmetallised paper layers between them.

The thickness of paper in the example is 2½ mils (.064 m/m.). Between the smoothing layer at *e* (Figure 1) and the conductive layer at *f* there are two groups of five thicknesses of paper computed as above indicated, these groups being separated by a conductive layer. There are in this region *e*—*f* two conductive layers with a five-layer spacing. In the region *f*—*g* there are also two groups of papers between conductive layers, each group consisting of six layers of paper. In the region *g*—*h* there are three groups of paper, each consisting of eight layers and separated by conductive layers. From *h* to *j* no conductive layers are inserted. By reference to Figure 4 it will be seen that for a region in which there is five-layer spacing between conductive layers (region *e*—*f*) the ratio of stress in gas space to stress in solid dielectric is 2.25. Accordingly, by the insertion of the conductive layers in this region the maximum stress is reduced to about 75% of the value that it would have had if there had been no conductive layers. The latter value is indicated at *k* in Figure 3 and the reduced value resulting from the presence of the conductive layers is shown at *a* on the stepped part of the curve. In this figure the part *a*—*b* corresponds to the region *e*—*f* of Figure 1: the part *b*—*c* to the region *f*—*g* of Figure 1 and the part *c*—*d* to the region *g*—*h* of Figure 1. In each of these parts of the stepped curve the sloping portion is related to the corresponding part of the curve H by the appropriate factor shown by Figure 4. It will be seen that the points *a*—*b*—*c* have substantially the same value as the point *d* which is on the curve J.

In order to ensure that under all conditions of manufacturing efficiency there shall not be a direct gas path between radially adjacent conductive layers, it is necessary to have at least two layers of plain impregnated insulating paper between the paper backings of the metallised paper strips forming the conductive layers. This condition sets the minimum limit to the closeness of the spacing of the conductive layers, (namely four layers, consisting of two supporting papers and two other papers) and, accordingly, limits the ratio of reduction of the stress in the gas spaces which can be effected by the insertion of conductive layers in accordance with the invention. The example shows how, by adjusting the spacing to different values, the stress in the gas spaces in the dielectric region near the conductor, can be kept down and maintained within a small range of values until the point is reached at which the stress in gas spaces, without the insertion of conductive layers, would be in this range. Beyond this point no advantage, by way of stress reduction, can be obtained by the insertion of further conductive layers.

What we claim as our invention is:

1. An electric cable comprising a conductor, a dielectric, surrounding the conductor, and a conductive layer concentric with the conductor and within the dielectric, said conductive layer consisting of two overlying metallic helices in contact with each other, each of said helices being carried on a strip of insulating material, on the centre part of one surface thereof, leaving at each side a bare margin, one strip having the metal on the outside and the other strip having the metal on the inside, the two helices being

placed so that each continuously bridges over the gaps between the edges of the turns of the other, the two thus forming a complete conductive layer without exposing a metallic edge in a space between the turns of a carrying strip.

2. An electric cable comprising a conductor, a laminated dielectric, surrounding the conductor and consisting of helically lapped impregnated paper strips with gas-filled spaces between the turns and layers thereof, and a gapless conductive layer, concentric with the conductor, within the dielectric and formed of two metallic helices, in contact with each other and one over-lying the other and continuously bridging the gaps between the turns thereof, the edges of these helices being enclosed by impregnated paper so that they do not lie in the gas-filled spaces.

3. An electric cable comprising a conductor, a laminated dielectric, surrounding the conductor and consisting of helically lapped impregnated paper strips with gas-filled spaces between the turns and layers thereof, and a plurality of gapless conductive layers, concentric with the conductor, spaced apart within the dielectric and each consisting of two overlying metallic helices in contact with each other, each of said helices being carried on a strip of insulating material, on the centre part of one surface thereof, leaving at each side a bare margin, one strip having the metal on the outside and the other strip having the metal on the inside, the two helices being placed so that each continuously bridges over the gaps between the edges of the turns of the other, the two thus forming a complete conductive layer without exposing a metallic edge in a space between the turns of a carrying strip.

4. In the manufacture of an electric cable, having a conductor and a dielectric surrounding the conductor and consisting of helically lapped impregnated paper strips with gas-filled spaces between the turns and layers thereof, the step of providing for the reduction of the electric stress in the gas-filled spaces in the part of the dielectric near the conductor by inserting, in the said part, a plurality of electrically isolated gapless conductive layers, concentric with the conductor and spaced apart by a small number of layers of impregnated paper, each of said conductive layers consisting of two metallic helices in contact with each other, each of said helices being carried on a strip of insulating material, on the centre part of one surface thereof, leaving at each side a bare margin, one strip having the metal on the outside and the other strip having the metal on the inside, the two helices being placed so that each continuously bridges over the gaps between the edges of the turns of the other, the two thus forming a complete conductive layer without exposing a metallic edge in a space between the turns of a carrying strip.

5. In the manufacture of an electric cable, having a conductor and a dielectric surrounding the conductor and consisting of helically lapped impregnated paper strips with gas-filled spaces between the turns and layers thereof, the step of providing for the reduction of the electric stress in the gas-filled spaces in the part of the dielectric near the conductor by inserting, in the said part, a plurality of electrically isolated gapless conductive layers, concentric with the conductor and spaced apart by a small number of layers of impregnated paper, this number being a minimum directly adjacent the conductor and increasing outwardly therefrom.

6. In the manufacture of an electric cable, having a conductor and a dielectric surrounding the conductor and consisting of helically lapped impregnated paper strips with gas-filled spaces between the turns and layers thereof, the step of providing for the reduction of the electric stress in the gas-filled spaces in the part of the dielectric near the conductor by inserting, in the said part, a plurality of electrically isolated gapless conductive layers, concentric with the conductor and spaced apart by a small number of layers of impregnated paper this number being in the range of 4 to 6 directly adjacent the conductor and increasing outwardly therefrom.

CHARLES JAMES BEAVER.
EDWARD LESLIE DAVEY.