Jan. 12, 1937. C. J. BEAVER ET AL 2,067,170

ELECTRIC CABLE

Filed Aug. 15, 1933

Fig. 1.

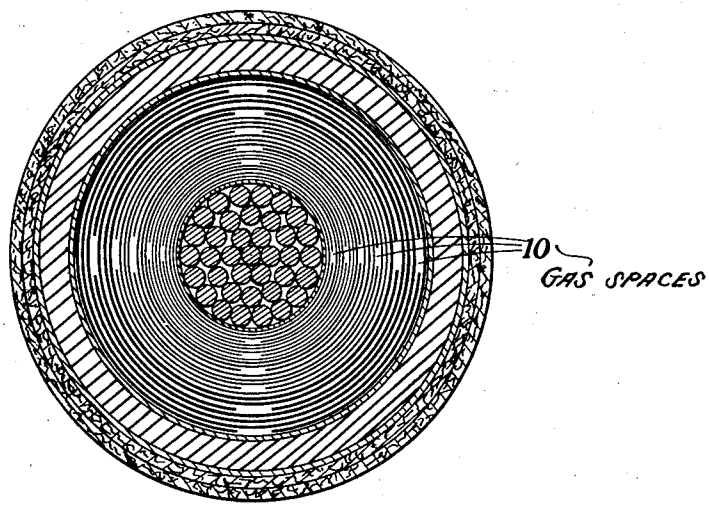
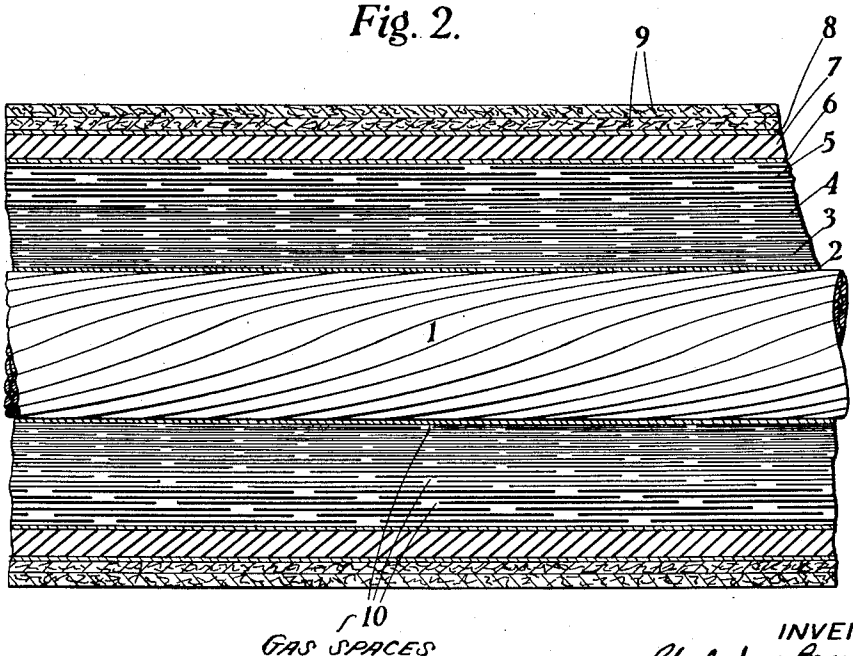


Fig. 2.



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ELECTRIC CABLE

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11 Claims. (Cl. 173—264)

It is well known that in high voltage cables of the paper insulated lead covered type, as at present manufactured, the presence of remanent or occluded air or gas is very undesirable because of the risk of it being ionized at high electric stresses and thereby producing local conditions tending to the breakdown of the dielectric.

By the common method of impregnation, in which the cable, previously lapped with paper, is dried and impregnated in vacuo with oil or compound (hereinafter, for convenience, spoken of as compound), it is recognized that it is impossible to eliminate entirely residual air and gas.

Further, this method imposes comparatively low limits on the viscosity of the impregnating compound in order that it may penetrate the wall of dielectric.

The result is that, while the residual air or gas is usually finely divided and uniformly distributed as very small bubbles or in solution in the impregnating compound of the dielectric when the cable is newly made, and the dimensions of the occlusions are such that the gas is not ionizable until much higher stresses than those corresponding to the working voltage have been applied, the said dimensions are liable to become altered by aggregation after the cable has been heated, so that ionization may then occur at lower stresses.

This aggregation is permitted by the mobile character of the impregnating compound, which is necessitated, as mentioned, by the requirements of penetration in the impregnation process. On the other hand if it is attempted to impregnate more fully, so that residual gas is much reduced, the dilation of the impregnating compound—unrelieved by gaseous compression in the dielectric—distends the lead sheath when the cable is heated under load, so that on cooling, low pressure spaces, containing gas ionizable under working conditions, tend to form in the dielectric.

In order to overcome these drawbacks of lead distension and/or gas aggregation, producing conditions under which the residual gas in an impregnated paper dielectric may become ionizable under working conditions, in accordance with the present invention a new combination of conditions within the cable is provided. One of the conditions is that spaces of definite and substantially invariable dimensions are provided for the gas present in the cable. The other condition is that the gas is continuously maintained under a pressure substantially below atmospheric pressure. It is well known that for each thickness of gas layer the ionization voltage falls continuously as the pressure of the gas is reduced until a critical pressure (hereinafter called the critical value) is reached; below this pressure the ionization voltage rises rapidly. The pressure in the present case is made so low, having regard to the dimensions of the spaces, that the gas therein will not be ionizable in the conditions under which the cable will work. This pressure is adjusted to be below the critical value for the largest radial dimension of any of the gas spaces in the cable so as to take advantage of the relatively high ionization voltage obtained in that region.

The invention is applicable both to cases where the paper is impregnated and to cases where the paper is unimpregnated. It is also applicable to other dielectrics than paper which are applied in a similar manner, for instance, to the material known as varnished cambric. For convenience in the following description the solid dielectric material will be spoken of as paper.

The dimensions of the spaces are assured by forming the spaces in the process of lapping on the paper layers so that they are determined radially by the thickness of the paper, and longitudinally by the spacing of the lappings in each layer. Where impregnated paper is to be used steps are taken to provide that the spaces between the lappings of paper are substantially clear of free compound, that is the compound is retained in the paper and on its surface.

In preparing impregnated paper for use in the manufacture of a cable in accordance with the present invention it is impregnated before application to the conductor with a compound having such a setting point as to ensure that physical stability of the impregnated paper is maintained up to a temperature well above the maximum reached in the working conditions of the cable. The impregnation may, for instance, be carried out as set out in the specification of U. S. Patent 1,752,972 or of U. S. Patent No. 1,958,984.

In addition to the impregnation the paper may be provided with a lubricating film as described in the said specifications. This film is preferably applied to one side of the paper only and is of very small thickness. It may, for instance, consist of a coating of petroleum jelly having a high viscosity and set point.

The impregnating treatment of the cable is completed by the operations on the paper above described. There is no subsequent addition of

compound, either during the lapping of the paper or to the completed paper dielectric.

An example of a cable embodying the present invention is illustrated diagrammatically in the accompanying drawing of which Figure 1 shows a transverse section and Figure 2 shows a longitudinal section.

In this cable the conductor 1 is covered with a thin metal tape or foil 2 and is lapped with layers or laminae of paper strip indicated by the reference numerals 3, 4 and 5. Over the outside of this dielectric material is placed a metallized layer 6 (preferably perforated) and over this the lead sheath 7 is applied. To the outside of the lead sheath is applied a metal reinforcing tape 8 and this is protected in the usual way by layers of impregnated fabric 9.

The metal tape 2, the metallized paper 6, the reinforcing tape 8 and the fabric layers 9 will as usual be lapped on helically. No attempt has been made to show this in the drawing.

The thin metal tape 2, lapped on the conductor 1, performs the known function of reducing local intensities of electric stress and also gives a definite inner cylindrical surface to the dielectric layer.

Instead of using this tape the desired results can be obtained by forming (either before or after stranding) the component wires of the outermost layer of the conductor in such a way as to give a smooth outer surface to the conductor. Alternatively a thin lead tube covering the conductor as a whole may be used as described in the specification of U. S. Patent No. 1,256,863.

It will be seen from the drawing how the dimensions of the gas spaces 10, between adjacent turns of the paper are fixed by (1) the spacing apart of adjacent turns and (2) by the thickness of the paper laminae. The former determines the longitudinal width of the spaces and the latter, the radial depth thereof. The metal tape 2 forms the inner surface of the innermost gas spaces. The metallized paper layer 6 forms the outer surface of the outermost gas spaces It will be understood that any gas which may be found in spaces between the metallized paper layer 6 and the sheath 7 will not be subject to electric stress. The same remark applies to the gas between the tape 2 and the wires of the conductor 1 and in the interior of this conductor.

From the preceding description of a single core cable it will be readily recognized how the invention may be embodied in cables having more than one core. It will be understood that the precautions taken to secure the absence of free compound must be extended to the material used for the fillers between the cores (where these are impregnated) as well as to any belt insulation which may be used in addition to the insulation of the individual cores.

Accurate predetermination of the spaces for the gas formed between adjacent turns of each helically applied layer of impregnated or unimpregnated paper results from the choice of a suitable thickness of paper and the staggering of successive layers so that none of the helical spaces are directly superposed. This last condition can be attained, for instance, by lapping the layers of impregnated paper on the cable by means of a machine of the type in which the cable rotates and the heads from which the paper is paid out are stationary and the relative positions of the paper strips accurately maintainable on undergoing continuous observation Such a machine is described in U. S. A. Patent No 1,591 736 It is to be understood however that the immersion of the cable in compound during lapping, which is described in that specification, is not to be employed in the present case. The strips of the paper are lapped on the cable in air which is preferably kept below normal humidity and the cable is then sheathed with lead or lead alloy, to which reinforcement may be applied as protection against external influences. After this the air enclosed in the dielectric, which is chiefly located in the spaces provided between the turns of paper, together with the other air in the cable, is evacuated to the desired extent. It may be replaced by an inert gas, such as nitrogen, carbon dioxide, helium, neon or other suitable gas. The process of removal of air and filling with gas may be facilitated by a repeated flooding and exhausting of the gas into and from the cable and by the application of heat to the cable intermittently or continuously, either by external means or by the passage of current through the conductor or conductors or by both of these. The final step in all cases is to evacuate the cable to obtain the desired low pressure, the cable having been sealed at the ends in order to prevent leakage inward.

The choice of the radial dimensions of the gas spaces and of the gas pressure will depend upon a number of conditions. It will however generally be advantageous to make the gas spaces at the surface of the conductor of small radial dimensions, for instance, one and a half thousandths of an inch. By increasing the thickness of the layers or wrappings of paper from the conductor outwards, the radial dimensions of the gas spaces may also be increased, taking advantage of the fact that the intensity of electric stress decreases from the surface of the conductor outwards. With such dimensions and with an absolute pressure of the order of 0–10 millimetres of mercury, conditions can be obtained which permit a very high voltage to be applied without obtaining ionization. It will be understood that the figures given are only by way of example.

Under no working conditions can the internal pressure exceed the external atmospheric pressure. The expansion of the solid dielectric which may occur will be compensated by a comparatively small change of pressure in the gas spaces. Accordingly no sheath distention can occur and no reinforcement of the sheath to deal with this will be required.

What we claim as our invention and desire to secure by Letters Patent is:—

1. An electric power cable comprising a conductor, an enclosing sheath and a laminated dielectric layer between the conductor and the sheath, said dielectric having spaces of predetermined dimensions and positions distributed through the laminations, these spaces having a radial depth which increases from the conductor outwards, and gas in these spaces at a pressure less than the critical value for the largest radial dimension of any of said spaces.

2. An electric power cable comprising a conductor, an enclosing sheath and a laminated dielectric layer between the conductor and the sheath, said dielectric having spaced apart interstices in the laminations at predetermined intervals and of predetermined sizes, the radial depth of said interstices increasing from the conductor outwards, and gas in said interstices at a pressure below atmospheric and less than the critical value for the largest radial dimension of any of said interstices.

3. An electric cable comprising a conductor, an

enclosing sheath and a dielectric material between the conductor and the sheath, said material being constituted by turns and laminae of paper tape with spaces of definite and substantially invariable dimensions between the turns and of increasing radial dimensions from the conductor outwards, said tape being fully impregnated with highly viscous compound which is confined to the paper under all working conditions, and gas occupying all said spaces, said gas being at a pressure substantially below atmospheric and less than the critical value of the largest radial dimension for any of said spaces.

4. An electric cable comprising a conductor, an enclosing sheath and a dielectric material between the conductor and the sheath, said material being constituted by turns and laminae of paper tape with spaces of definite and substantially invariable dimensions between the turns and of increasing radial dimensions from the conductor outwards, said tape being fully impregnated with oil compound which has a setting point above the working temperature of the cable, and gas occupying all the said spaces, said gas being at a pressure substantially below atmospheric and less than the critical value for the largest radial dimensions of said spaces.

5. An electric cable comprising a conductor, an enclosing sheath and a dielectric layer between the conductor and the sheath, said layer comprising wrapped paper impregnated with highly viscous compound and gas at a pressure substantially below that of the atmosphere, which gas occupies spaces in the dielectric layer of dimensions predetermined in size so as to avoid ionization of gas and which spaces are substantially invariable in position and dimensions and are substantially clear of free compound under all working conditions, which spaces are distributed through the dielectric layers.

6. An electric cable comprising a conductor, an enclosing sheath and a laminated dielectric layer between the conductor and the sheath, said layer comprising wrapped paper impregnated with highly viscous compound, and gas, which gas occupies spaces in the dielectric layer of substantially invariable dimensions which are bounded by the turns and laminae of the paper, which spaces are substantially clear of free compound under all working conditions, said gas being at a pressure substantially below that of the atmosphere and less than the critical value for the largest radial dimension of any of said spaces.

7. An electric cable comprising a conductor, and enclosing sheath and a laminated dielectric layer between the conductor and the sheath, said layer comprising paper impregnated with a compound which has a high setting temperature above the range of the working temperature of the cable and which compound is thereby retained in and confined to the paper under all working conditions, said layer also comprising gas, which gas occupies spaces of substantially invariable dimensions, which spaces are bounded by the turns and laminae of the paper, said gas being at a pressure substantially below that of the atmosphere and less than the critical value for the largest radial dimension of any of said spaces.

8. An electric cable comprising a conductor, an enclosing sheath and a dielectric layer between the conductor and the sheath, said dielectric layer comprising wrapped paper impregnated with a highly viscous compound, said layer having helical spaces therein of mechanically predetermined locations and dimensions such that the dielectric strength of any radial dimension of said layer is predetermined, said spaces having gas therein at a pressure substantially below atmospheric and less than the critical value for the largest radial dimension of any of said spaces, the spaces being formed between edges of adjacent turns of paper and between surfaces of concentric wrappings.

9. An electric cable comprising a conductor, an enclosing sheath and a dielectric layer between the conductor and the sheath, said layer having helical spaces therein of mechanically predetermined locations and dimensions, said dielectric layer comprising wrapped paper impregnated with a highly viscous compound, the spaces being formed between edges of adjacent turns of paper and between surfaces of concentric wrappings, said spaces having gas therein at a pressure substantially below atmospheric and below the critical value for the largest radial dimension of said gas spaces, the dielectric strength of each part of said layer being predetermined by the dimensions of the spaces and the gas pressure.

10. An electric cable comprising a conductor, an enclosing sheath and dielectric material between the conductor and the sheath, said material being constituted by definitely spaced turns and layers of paper tape of predetermined thickness, which tape is fully impregnated with a highly viscous compound which is confined to the paper under all working conditions, all the spaces between the turns and layers of paper tape being occupied by gas at a pressure substantially below that of the atmosphere and below the critical value for the largest radial dimension of any of said spaces.

11. An electric cable comprising a conductor, an enclosing sheath and dielectric material between the conductor and the sheath, said material being constituted by definitely spaced turns and layers of paper tape of predetermined thickness, which tape is fully impregnated with oil compound which has a setting point higher than the working temperature of the cable, whereby the compound is confined to the paper under all working conditions, all the spaces between the turns and layers of paper tape being filled with gas at a pressure substantially below that of the atmosphere and below the critical value for the largest radial dimensions of any of the spaces.

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