

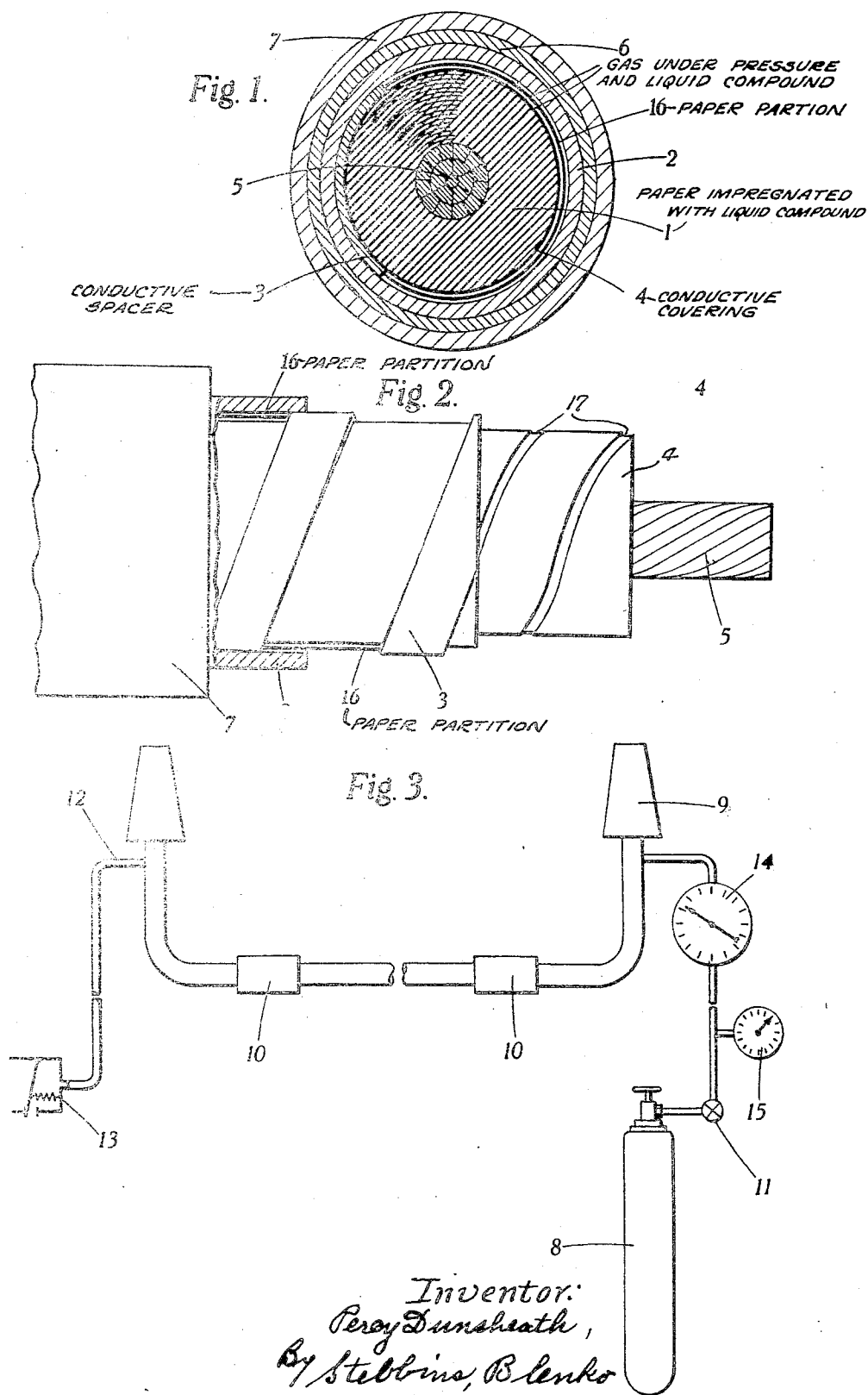
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ELECTRIC CABLE

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ELECTRIC CABLE

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In connection with high voltage electric cables having impregnated paper dielectrics, it has been realised that, in practice, it is impossible to eliminate entirely gas from the dielectric. Traces may be retained in the paper lappings in spite of the evacuation before impregnation and small quantities of gas may be carried into the dielectric with the oil in spite of the degasifying treatment to which it is subjected. It is also well recognised that the presence of these traces of gas constitutes a source of danger to the cable owing to the possibility of ionisation of the gas, unless it is maintained in bodies of small thickness and at high pressure while located within the electric field.

On the other hand it has been noted that the presence of gas distributed in the dielectric is advantageous in that it provides a cushioning effect against the production of excessive pressure changes within the cable when the impregnating material expands and contracts as changes of temperature occur during the working life of the cable. When gas under pressure is maintained in contact with a liquid or semi-liquid impregnating material, such as mineral oil, petroleum jelly, or oil compound, it passes into solution to an appreciable extent and the cushioning effect on pressure changes, accordingly, is due largely to gas going into and coming out of solution. In such cases the impregnating material behaves as if it were an elastic body owing to the liberation of small gas bubbles in it on fall of pressure and the re-absorption of these bubbles when the pressure rises again. By the present invention a cable is provided in which this gas solution cushioning effect is utilised particularly effectively and the arrangement is such as to ensure reasonable uniformity of the gas and oil mixture throughout the length of the cable and to ensure the exposure of maximum oil/gas surface for the interchange of gas into and out of the solution, while providing the possibility of the use of an impregnating material which has low dielectric loss and a low rate of rise of loss with rise of temperature. This is of importance for cables designed for very high working voltages, since the value of the dielectric losses is a factor of very great influence in determining the design and rating of the cable, particularly in cases, like the present, where the danger of ionisation is dealt with by the use of a sufficiently high pressure combined with appropriately small dimensions of the gas spaces in the electric field.

A cable constructed in accordance with the present invention comprises a paper dielectric

which has been impregnated with a material which is fluid under all working conditions of the cable, and has then been drained so as to remove the greater part of the impregnating material which is not retained within the structure of the paper itself. This dielectric is enclosed in a sheath and the cable is so constructed that gas can flow longitudinally through the cable, while having access to the dielectric, so that it can pass into solution in the impregnating material therein. This gas under working conditions is maintained at a pressure substantially above atmospheric pressure. This pressure may be from 5 atmospheres upwards. In practice a value of 14–20 atmospheres will generally give an advantageous design.

The usual method of lapping on the paper in the form of strips in superposed layers, each strip taking a helical path with a space between adjacent turns, has the effect of providing helical passages (Figure 2) between the turns extending from end to end of a length of cable. These passages will serve for the longitudinal flow of the gas. In many cases, however, it will be an advantage to supplement them by an external duct (or ducts) between the dielectric and the sheath. Such a duct lies outside the electric field, and may be parallel with the axis of the cable or may be helical.

In the draining of the dielectric it is not intended to remove all free impregnating material and there is no drying action. It is simply desired to remove the bulk of that material which is free to flow within the spaces in the dielectric and elsewhere in the cable and thus to expose the maximum oil surface to the superimposed gas. When the impregnating material is a light oil, draining can be done at ordinary temperatures. With more viscous oils, or compounds it will be necessary to assist draining by raising the temperature above normal.

An indication of the effect of draining is given by the following comparison. In a fully impregnated paper dielectric the volume of the dielectric is about equally divided between paper and impregnant. In a drained dielectric, in accordance with the present invention, the impregnant is equal to only from 65% to 40% of the volume of the paper. The precise figure is dependent upon the thickness and quality of the paper and the viscosity and other properties of the impregnant and upon the method of procedure. In general, it is preferred to work in the lower part of the range which can be obtained by the methods hereinafter described.

Examples of suitable impregnating materials are:

- (a) Mineral oils of paraffinic or naphthenic base, both light and heavy, having a viscosity which is not greater than 3,000 Redwood seconds at 60° C. and not greater than 400 Redwood seconds at 100° C. and a power factor which is not greater than 0.005 at 100° C.

(b) Petroleum jelly.

- (c) Compounds of mineral oil (such as defined in (a) above) with wax-like materials (for instance opal wax) giving a mixture of similar characteristics to petroleum jelly. Suitable proportions by weight are 90% mineral oil and 10% wax.

- (d) Compounds of mineral oil (such as defined in (a) above) with rubber. Suitable proportions by weight are 96.5% oil and 3.5% rubber.

- In further description of the invention the accompanying diagrammatic drawing will be referred to. Figure 1 is a cross-section through a cable embodying the invention. Figure 2 is a side view of the cable with some of the outer parts removed. Figure 3 is a diagram of an installation.

- In cables where a duct is provided, it is formed at the outside of the dielectric. By providing a conductive coating on the outside of the dielectric the duct spaces between the dielectric and the sheath are screened from electric stress. Such a conductive coating will, as usual, be permeable by the impregnating material used and by gas.

- In the form (shown in Figures 1 and 2), which has certain advantages, a duct (or ducts) between the dielectric 1 and the sheath 2 is formed by coiling a strip 3 of spacing material round the dielectric in an open helix and applying a sheath over this spacer so as to leave a helical channel extending from end to end of the cable length. This spacing strip 3 is either formed of metal or provided with a conducting covering or insertion such that it establishes connection between the conductive covering 4 on the outside of the dielectric and the sheath and avoids the production of electric stress within the channel.

- It is preferable to divide the duct into two (or more) co-axial helical spaces by a partition 16 formed of paper. This partition will only be slowly permeated by gas, or impregnant, so that its general effect is to maintain any impregnant which drains out of the dielectric 1 in close contact with the covering 4, so that it may readily pass back into the dielectric, and maintain an unobstructed passage for the gas outside the partition 16.

- The conductor is preferably formed so that no appreciable quantity of impregnant can be contained within it. A "voidless" stranded conductor 5 is shown in Figure 1. On the outside of the lead sheath 2 is applied reinforcement indicated by 6 and this may be enclosed and protected against corrosion by an outer lead sheath 7.

- A suitable method of manufacture is as follows. The paper is lapped on the conductor in the usual way forming helical passages 17 between the turns and layers of paper and, after lapping is complete, the helical spacing strip 3 and the partition 16, which it supports, (if they are to be used) are applied and the conductor, dielectric and spacer are then subjected to drying, the inner sheath is then applied and this is followed by the reinforcement and the outer sheath. The impregnation is then carried out

by applying a vacuum by connection at one end of the inner sheath and a supply of impregnant under pressure by a connection at the other end of the sheath; at the same time the cable is heated. A pressure of about 7 atmospheres may be used and is maintained until the oil flows out freely at the vacuum end of the cable. This end is then closed and the pressure allowed to build up throughout the length of the cable. When this has been attained, draining is effected by disconnecting the oil supply and replacing it by a supply of hot dry gas, preferably nitrogen, under a pressure of about 14 atmospheres. The other end is then opened and the surplus impregnant is forced out by the pressure of the gas. A large part of the impregnant is removed in the first stage, which continues until the gas flows out freely at the far end of the cable. Further removal is obtained by allowing the gas to blow through the cable and carry impregnant with it as it drains from the paper dielectric. Where a duct is used this blowing out is made more effective by the use of a spacer 3 of comparatively small radial depth so that the space into which the impregnant drains is comparatively shallow radially. When the draining has been carried to the required degree the cable ends are capped and the cable is allowed to cool down. In so doing the impregnant contracts and moves towards the inner part of the dielectric and the pressure of the gas falls. The pressure of the gas in the cable when the latter is capped may be reduced so that when cooling has taken place the pressure has only a small value in excess of atmospheric. After laying and jointing the cable the full gas pressure is applied and gas is fed into the cable to cause the pressure to build up to the full value through the whole length of the cable.

As an alternative method, impregnation by the well-known procedure of immersion, in impregnant under pressure, of the dielectric on the conductor, prior to applying a sheath, can be adopted. In this case the draining is effected by removing the coil of cable core from the impregnant and allowing it to drain while maintaining it at a high temperature.

The form and condition of cable described ensures that gas has access to the dielectric throughout the length of the cable and at all points radially in the impregnated paper dielectric so that it may be absorbed by the impregnating material as required. Thereby reasonably uniform conditions are maintained at all points, and maximum accommodation for the solution of gas is provided.

By this means the pressure cushioning effect of the gas is obtained with a very small range of pressure corresponding to the range of temperature to which the cable is subjected when working. For instance, a cable constructed in accordance with the invention and having gas at a pressure of 14 atmospheres at the lower end of its temperature range and sealed off from the atmosphere and external gas supplies, would rise in pressure to about 15.5 atmospheres at the upper end of the temperature range. For a cable in which the dielectric is maintained substantially filled with impregnant and the cushioning gas is in an external duct, the rise of pressure would be much higher, being of the order of 21 atmospheres.

If impregnating material draining out of the dielectric into the duct tends to accumulate in a relatively large quantity in any locality, such

for instance, as in the lower part of a dip in the run of cable, it may be prevented from disturbing unduly the uniformity of the conditions of the system by providing a sufficient pressure difference between points of entry and exit of gas spaced apart along the cable to ensure that gas flows along the duct. This movement of gas will bring it into contact with the impregnating material and will also assist to redistribute this material. For the latter purpose the shallow form of the gas duct and the provision of the partition 16 is also advantageous in that the movement of gas along the inner part of the duct tends to drive in front of it any accumulation of oil and distribute it again to those parts of the cable from which it has drained. It is for this reason that a helical duct is preferable to a straight duct parallel with the axis of the cable. The former guides the oil round the cable so that it passes from the lower side, where it has accumulated, back to the upper side.

In an installation embodying cable of the kind indicated above, the cable, as above indicated, can be laid and jointed at normal pressure and the pressure raised by gas forced in subsequently.

If the conditions are such that redistribution of impregnant by gas movement is necessary, continuously or from time to time, there may also be provision for forcing gas in at appropriate points and withdrawing it, or permitting it to escape at other points so as to have a pressure gradient along the cable sufficient to cause the gas to flow, as explained. This arrangement may (as shown in Figure 3) comprise a pressure bottle 8 of gas connected to the cable at a terminal 9 or joint 10 through a controlling valve 11 in combination with an outlet 12 controlled by a release valve 13 at some other terminal or joint. The joints 10 provide through passage for the gas. The pressure gauge 15 and air flow meter 14 assist in making adjustments of the

valve 11 and indicate the gas conditions in the installation.

What I claim as my invention is:

1. A high voltage electric cable having a conductor, a body of dielectric material surrounding the conductor, said body being impregnated with material which is liquid under all working conditions of the cable, spacing means on the outside of said body and a sheath, surrounding said body and spacing means and forming therewith a helical duct, a liquid impregnant and free gas under pressure substantially above atmospheric in the duct and gas also in solution in the impregnant, and a partition in said duct, dividing it into two concentric portions, the partition being formed of material which is permeated only slowly by the impregnant and by the gas.

2. A high voltage electric cable, comprising a conductor, dielectric material surrounding the conductor, longitudinally communicating passages being provided at least in part by said dielectric material, a sheath enclosing the conductor, the dielectric material, and passages, the dielectric being composed of paper impregnated with a material, which is liquid under all working conditions of the cable, the volume of the impregnant in the cable being in the range 40% to 65% of the volume of the paper in the dielectric, and the longitudinally communicating passages containing free impregnant and gas under a pressure substantially greater than atmospheric which gas is also in contact with and in solution in the impregnant, and means for maintaining the gas pressure throughout the cable and a gas pressure gradient along the cable to cause movement of the gas along the cable, said moving gas serving as means to distribute impregnant in the passages of the cable, said means comprising supply means for gas under pressure and a release valve spaced apart along the cable.

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