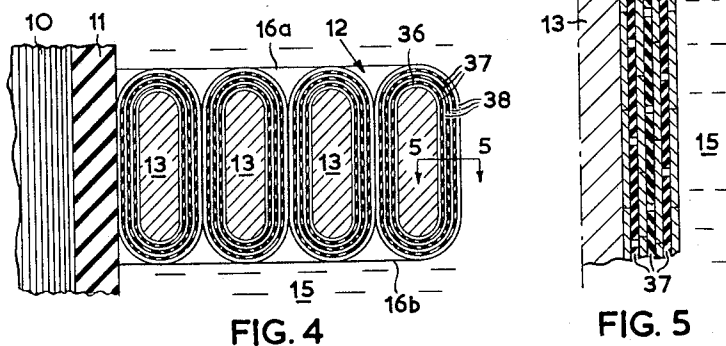
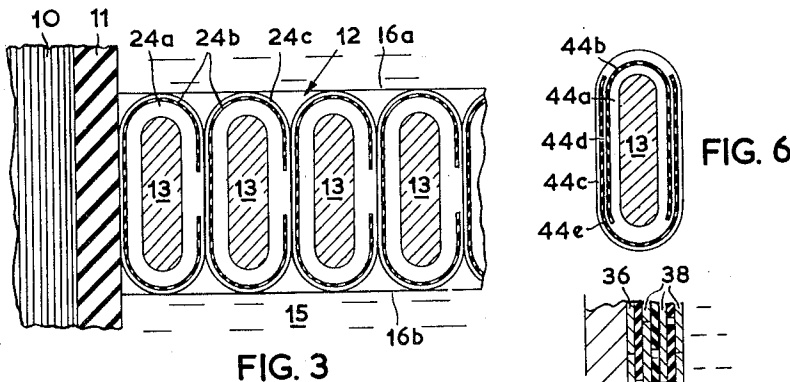
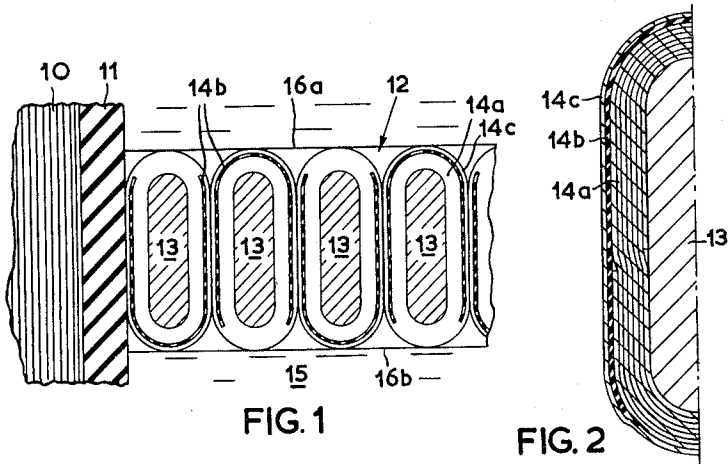


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OIL-IMMERSED ELECTRICAL APPARATUS HAVING
OIL-IMPREGNATED MAIN INSULATION PARTLY
COVERED BY LIQUID-IMPERVIOUS MATERIAL
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OIL-IMMERSED ELECTRICAL APPARATUS HAVING OIL-IMPREGNATED MAIN INSULATION PARTLY COVERED BY LIQUID-IMPERVIOUS MATERIAL

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This invention relates to electrical apparatus of the kind which is immersed in oil, and has for an object to provide improved insulation for such apparatus. One particular form of apparatus to which the invention is applicable is the high-voltage electrical transformer.

According to the invention, electrical apparatus of the kind which is immersed in oil comprises a plurality of electrical conductors which in use are at different potentials and adjacent to one another, each conductor being covered by a main insulating covering of a material which in use is impregnated by the oil and each conductor further having an insulating part-covering of a material which is impervious to liquids, the part-covering surrounding and partly but not wholly covering the main insulating covering so as to allow the impregnation of the main insulating covering with insulating oil but to restrict the absorption of water by said main covering.

According to a feature of the invention the electrical conductors are closely wound to form a coil having two main surfaces in contact with the oil, and the insulating part-covering of alternate conductors is disposed around that portion of the conductor which forms part of one of said main surfaces and the insulating part-covering of the intermediate conductors is disposed around that portion of the conductor which forms part of the other main surface.

According to another feature of the invention each conductor has a thin top covering which in use is impregnated by the oil, the conductors are closely wound to form a coil having two main surfaces in contact with the oil, and to have portions of said top covering forming a common interface between adjacent conductors and the insulating part-covering of each conductor is disposed around those portions of the conductor which form said main surfaces and the intermediate portion on one side only of the conductor. In the preferred arrangement the insulating part-coverings are similarly disposed on adjacent conductors, whereby the portion of the top covering which directly covers the main insulating covering on one conductor forms a common interface with the portion of the top covering which covers the intermediate portion of the part-covering of the adjacent conductor.

According to another feature of the invention the main insulating covering is in a laminated arrangement of continuous layers of a material which in use is impregnated by the oil, and each said continuous layer is surrounded by an interrupted layer forming an insulating part-covering of a material which is impervious to liquids, the interruptions in the layers of the insulating part-covering affording channels for the ingress of oil to the continuous layers of insulation but being staggered in respect of their positions in successive layers to render the paths for the ingress of liquid tortuous.

According to yet another feature of the invention the electrical apparatus comprises a first insulating part-covering of a material which is impervious to liquids disposed around more than half the periphery of the main insulating covering, a layer of material of the kind which in use is impregnated by insulating oil disposed around said first part-covering, and a second insulating part-

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covering of a material which is impervious to liquids disposed around more than half the periphery of said layer, the second part-covering extending around that portion of the periphery of the conductor not protected by the first part-covering and overlapping the latter.

The invention will now be described with reference to the accompanying drawings in which:

FIG. 1 shows schematically a sectional view of part of an electrical transformer core and a coil embracing the core, the coil consisting of conductors insulated in accordance with a preferred form of this invention;

FIG. 2 shows an enlarged sectional view of the insulation of half of one of the conductors shown in FIG. 1;

FIG. 3 is a view similar to that shown in FIG. 1 but embodying a different form of the invention;

FIG. 4 shows another view similar to that shown in FIG. 1 but embodying a third form of the invention;

FIG. 5 shows an enlarged sectional view on the line 5-5 of FIG. 4; and

FIG. 6 shows a sectional view of yet another form of conductor insulation embodying the invention.

Referring to the drawings, there is shown schematically part of a high-voltage power transformer, having a magnetic core 10 with a covering of insulation 11 surrounded by a coil 12 forming part of the high-voltage winding. The coil 12 is shown as comprising four turns 13 of a conductor, the turns being insulated from one another by insulation 14. It will be understood that the transformer includes a plurality of further coils 12, which together form the high-voltage winding, and also includes a low-voltage winding. These details are not shown since the invention relates, in the embodiment described, to the insulation of the high-voltage winding, though it may also be applied to the insulation of the low-voltage winding, though with less advantage. It will moreover be understood that the turns 13 are not necessarily of the same conductor, but for example two conductors may be wound together as described in United States Patent No. 2,453,552 of George Fletcher Stearn. The coil 12 is immersed in insulating oil in well-known manner when the transformer is in use.

If small quantities of water come into contact with paper insulation they are rapidly absorbed by the paper and a very large reduction in electrical strength occurs.

It is the object of this invention to provide an improved form of insulation which may be used with advantage in high-voltage power transformers and similar electrical apparatus to enable the insulation to withstand the adverse effects of a small amount of water contamination.

Referring to FIG. 2, a conductor 13 is shown to have a main covering of insulation 14a, a thin part-covering of insulation 14b and a thin top covering of insulation 14c. The insulation 14a is of the kind which in use is impregnated by the oil 15. It may for example be paper insulation of the kind conventionally used in transformers. The part-covering 14b is an insulating covering of material which is impervious to liquids. Three examples of materials of this kind which may be employed are polyethylene terephthalate film known under the registered trademark "Mylar," polycarbonate film known under the registered trademark "Makrofol," and irradiated polyethylene film which has been irradiated with a dose exceeding 40 megarads. As shown in FIG. 2 this part-covering extends around the top and the two sides of the conductor cross-section to protect the main insulating covering 14a on three sides of the conductor against the ingress of small quantities of water. The thin top covering 14c is of the kind which in use, is impregnated by the oil 15, but the part-covering 14b is impervious to liquids. The impregnation of the main covering 14a with oil therefore takes place where the top covering 14c and main covering 14a are in contact, the oil penetrating through-

out the main covering 14a beneath the part-covering 14b which does not extend around the bottom of the conductor 13 shown in FIG. 2. It will be appreciated that the insulation is impregnated with oil, as is customary, before the apparatus is placed in use. The thin top covering 14c serves to retain the part-covering 14b in position.

Whereas the part-covering 14b does not prevent the ingress of oil into the main insulating covering 14a and whereas, since the cellulose in a typical paper insulation 14a has a much greater affinity for water than for transformer oil it cannot completely prevent the ingress of water into the main insulating covering 14a, it will nevertheless provide a tortuous path which will greatly retard this ingress of water, particularly as the insulating covering is previously impregnated with oil. The affinity for water of a typical paper insulation is accelerated when the apparatus is energized. Under these conditions the high potential gradients in the vicinity of the conductors 13 attract droplets of water in oil and thereby accelerate the ingress of water into the main insulation 14a. However, in company with this energization of the apparatus the displacement currents between the conductors will, in passing through any moisture content of the oil, produce a heating effect which will tend to vaporize the water and drive it out of the insulation. The action of the part-covering 14b is therefore to provide a tortuous path which retards the entry of moisture into the main insulation 14a thus enabling the displacement currents to have a greater effect in driving the moisture out of the insulation before it can promote a breakdown.

It is of particular importance in applying the invention to best advantage to adopt a configuration of protected conductors which takes the above factors into account and in which the disposition of the part-coverings 14b is employed to best advantage. An example of such a configuration is shown in FIG. 1 where the conductors 13 form a coil 12 having two main surfaces 16a, 16b (the upper and lower surfaces of the coil, as shown) in contact with the oil. The part-coverings 14b on every alternate conductor surround two sides and the top of the conductor, whereas the intermediate conductors have their two sides and bottom protected by the part-coverings 14b.

This arrangement is of particular advantage because if a droplet of water is attracted to a point where the top insulating coverings 14c of two adjacent conductors 13 are in contact, one of these conductors has its main insulating covering 14a at this point very well protected against the ingress of moisture from this droplet since its part-covering 14b extends for a substantial distance from this point in both senses. Thus if the moisture of this droplet is absorbed from the top covering 14c of the other conductor into its main insulation 14a where it is not protected by the part-covering 14b, the weakening of the insulating properties caused by this moisture will only produce a local weakening in the insulation of one of the conductors. If the part-covering 14b were absent on adjacent conductors, the moisture of this droplet would be absorbed by the main insulation 14a of both conductors and the weakened electrical regions in the insulation would be in contact with one another. The chances of an electrical breakdown between the adjacent conductors are therefore greatly reduced in the arrangement shown in FIG. 1 compared with an arrangement in which the part-covering is not used, or is disposed so that the top covering and main covering are in contact at points where the adjacent conductors are contiguous.

FIG. 3 shows an alternative arrangement of the part covering 24b (corresponding to part-covering 14b) which is also operative to safeguard against the deterioration of the insulation caused by moisture in the oil in a similar manner to that described above. However, in this arrangement the part-coverings 24b are C-shaped whereas the part-coverings 14b in FIG. 1 are U-shaped. The part-coverings 24b provide a waterproof shield against the direct ingress of moisture from the oil 15 into the main

insulating covering 24a (corresponding to the covering 14a in FIG. 1) on both main surfaces of the coil formed by the conductors 13.

As a feature of this invention is the tortuous path provided for the penetration of both oil and water into the main insulating covering, there are other forms of conductor insulation which may apply the invention with advantage. For example, a laminated insulation consisting of alternate layers of paper and of a material which is impervious to liquids (such as the examples given above) may be used to form the insulating covering around the conductor. In this case, to provide suitable channels for the impregnation of the paper with oil, the waterproof layers of insulation are perforated or otherwise interrupted and the perforations or interruptions in one layer are preferably staggered relative to those in another layer to render the path through which oil permeates through the paper tortuous. The perforations or interruptions are also preferably arranged to guide the ingress of liquid along a path whose general direction does not follow a line of electric force emanating from the conductor.

One preferred form of this embodiment of the invention is illustrated schematically in FIGS. 4 and 5.

Referring to these figures the insulation around each conductor 13 consists of a first layer 36 of paper tape insulation followed by alternate layers of tape made of "Mylar" 37 (or of another material which is impervious to liquids, such as the other two examples given above) and paper 38 respectively, the paper tape being butt lap wound and the "Mylar" tape being wound with a small gap between laps. The gap may in a typical insulation be $\frac{1}{16}$ inch and in the preferred arrangement shown in FIG. 5 this gap occurs one-third of the way across the paper strip. In this latter case it is arranged that the paper tape is $\frac{1}{16}$ of an inch wider than the "Mylar" tape. It will be appreciated that the insulation extends in this fashion for substantially the whole extent of the conductor.

In FIG. 6 there is shown a fourth embodiment consisting of a variation of the arrangement shown in FIGS. 1 and 2. In this embodiment the main covering of insulation 44a (corresponding to insulation covering 14a of FIG. 1) is surrounded first by a U-section part-covering 44b of a material which is impervious to liquids (such as the examples given above). The part-covering 44b extends around the top and two sides of the conductor cross-section, and is surrounded by a layer 44d of material of the kind which is impregnated by insulating oil. The layer 44d is surrounded in turn by a further U-section part-covering 44e of a material which is impervious to liquids, the part-covering 44e extending around the bottom and two sides of the conductor. The part-covering 44e is surrounded by a thin top covering 44c: conveniently the main covering 44a, the layer 44d and the top covering 44c are of the same material, which may (as mentioned above) be paper insulation of the kind conventionally used in transformers.

It will be seen that this arrangement also allows the main insulating covering 44a to become impregnated with insulating oil 15, but provides a tortuous path for the ingress of any water droplets which may be contained in the oil. In this way the risk of breakdown of the insulation of the conductor 13 is greatly reduced.

In all the embodiments described it is preferred to use a waterproof material for the part-coverings 14b, 24b, 44b, 44e and the layers 37 which has the same dielectric constant as the oil-impregnated insulation. The polyethylene terephthalate film known as "Mylar" has approximately the same dielectric constant as the oil-impregnated paper used in conventional transformers.

What I claim as my invention and desire to secure by Letters Patent is:

1. Electrical apparatus of the kind which is immersed in oil comprising a plurality of electrical conductors which

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in use are of different potentials and adjacent to one another and are closely wound to form a coil having two main surfaces in contact with the oil, each conductor being covered by a main insulating covering of a material which in use is impregnated by the oil and each conductor further having an insulating part-covering of a material which is impervious to liquids, the part-covering surrounding and partly but not wholly covering the main insulating covering so as to allow the impregnation of the main insulating covering with insulating oil but to restrict the absorption of water by said main covering and wherein the insulating part-covering of alternate conductors is disposed around that portion of the conductor which forms part of one of said main surfaces and the insulating part-covering of the intermediate conductors is disposed around that portion of the conductor which forms part of the other main surface.

2. Electrical apparatus as claimed in claim 1 wherein the dielectric constant of the material which is impervious to liquids is approximately the same as that of the material of the main insulating covering.

3. Electrical apparatus of the kind which is immersed in oil comprising a plurality of electrical conductors which in use are at different potentials and adjacent to one another, and are closely wound to form a coil having two main surfaces in contact with the oil, each conductor being covered by a main insulating covering of a material which in use is impregnated by the oil, by an insulating part-covering of a material which is impervious to liquids, and by a thin top covering which in use is impregnated by the oil, said top covering forming a common interface between adjacent conductors, the part-covering surrounding and partly but not wholly covering the main insulating covering so as to allow the impregnation of the main insulating covering with insulating oil but to restrict the absorption of water by said main covering, and the insulating part-covering of each conductor being disposed around those portions of the conductor which form said main surfaces and the intermediate portion on one side only of the conductor.

4. Electrical apparatus as claimed in claim 3 wherein the dielectric constant of the material which is impervious to liquids is approximately the same as that of the material of the main insulating covering.

5. Electrical apparatus as claimed in claim 3 wherein the insulating part-coverings are similarly disposed on adjacent conductors, whereby the portion of the top covering which directly covers the main insulating covering on one conductor forms a common interface with the portion of the top covering which covers the intermediate portion of the part-covering of the adjacent conductor.

6. Electrical apparatus as claimed in claim 5 wherein the dielectric constant of the material which is impervious to liquids is approximately the same as that of the material of the main insulating covering.

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7. Electrical apparatus of the kind which is immersed in oil comprising a plurality of electrical conductors which in use are at different potentials and adjacent to one another, each conductor being covered by a main insulating covering of a material which in use is impregnated by the oil, and each conductor further having an insulating part-covering of a material which is impervious to liquids, the main covering and part-covering forming a laminated arrangement, the main covering being in continuous layers and the part-covering in the form of interrupted layers, the part-covering surrounding the main insulating covering, and the interruptions in the part-covering affording channels for the ingress of oil to the continuous layers of insulation but being staggered in respect of their positions in successive layers to render the paths for the ingress of liquid tortuous to restrict the absorption of water by said main covering.

8. Electrical apparatus as claimed in claim 7 wherein the dielectric constant of the material which is impervious to liquids is approximately the same as that of the material of the main insulating covering.

9. Electrical apparatus of the kind which is immersed in oil comprising a plurality of electrical conductors which in use are at different potentials and adjacent to one another, each conductor being covered by a main insulating covering of a material which in use is impregnated by the oil, and each conductor further having a first insulating part-covering of a material which is impervious to liquids disposed around more than half the periphery of the main insulating covering, a layer of material of the kind which in use is impregnated by insulating oil disposed around said first part-covering, and a second insulating part-covering of a material which is impervious to liquids disposed around more than half the periphery of said layer, the second part-covering extending around that portion of the periphery of the conductor not protected by the first part-covering and overlapping the latter, so as to allow the impregnation of the main insulating covering with insulating oil but to restrict the absorption of water by said main covering.

10. Electrical apparatus as claimed in claim 9 wherein the dielectric constant of the material which is impervious to liquids is approximately the same as that of the material of the main insulating covering.

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