July 7, 1942. I. W. A. KIRKWOOD 2,288,969

ELECTRIC INSULATOR INCLUDING STRESS-GRADING CONDENSER LAYERS

Filed March 3, 1941 2 Sheets-Sheet 1

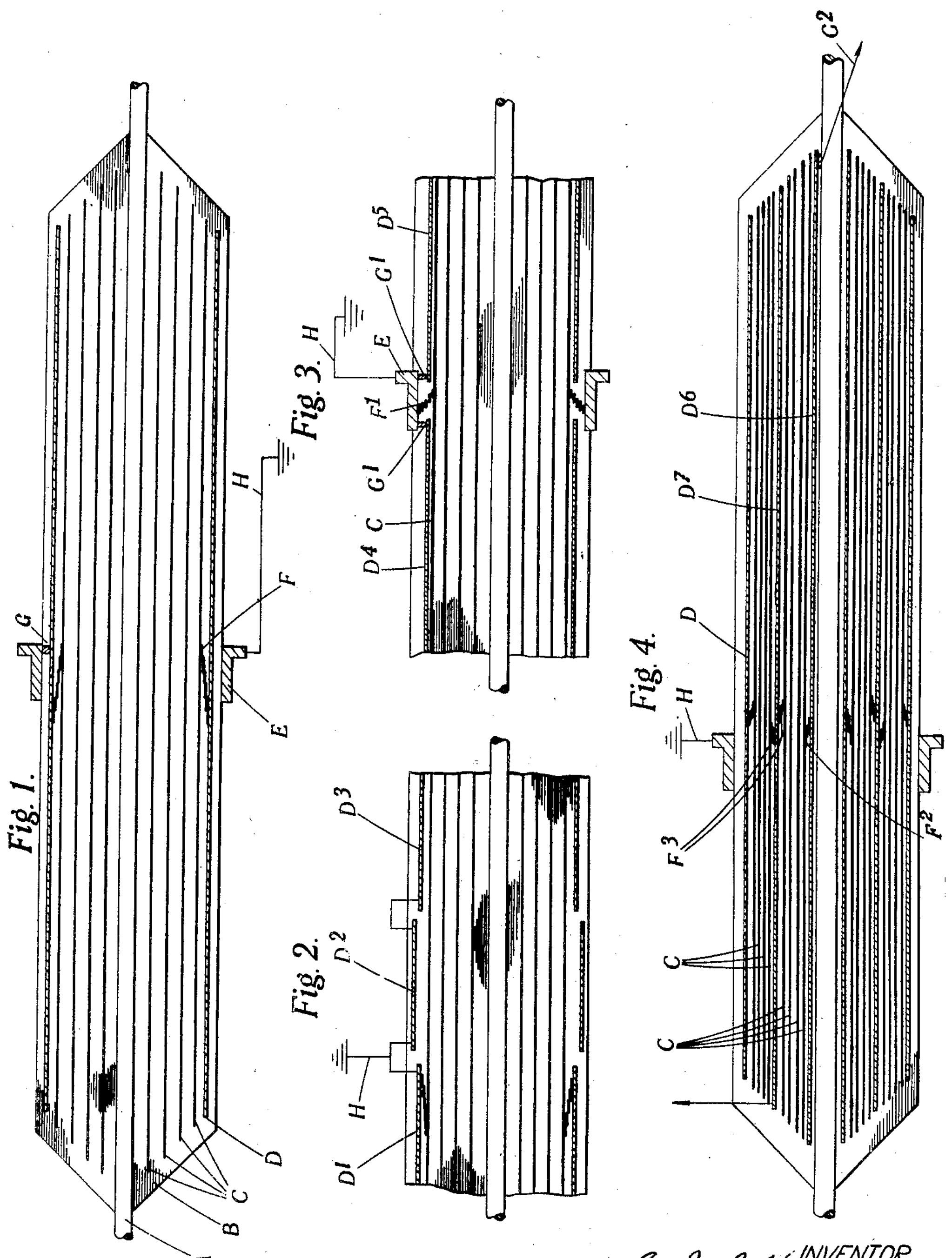

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FIG. 5.

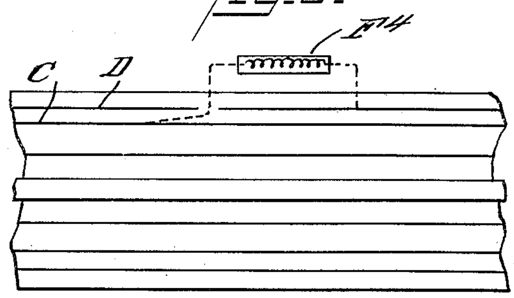


FIG. 6.

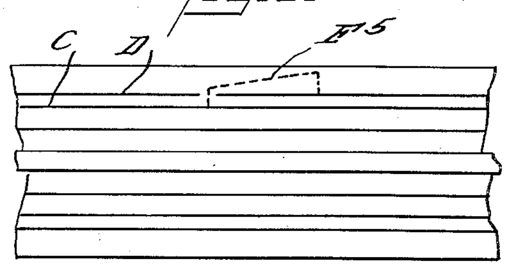
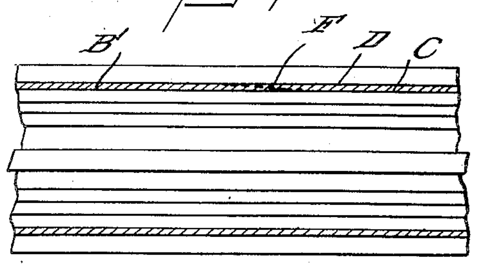


FIG. 7.



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ELECTRIC INSULATOR INCLUDING STRESS-GRADING CONDENSER LAYERS

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16 Claims. (Cl. 174—143)

This invention relates to electric insulators including stress-grading condenser layers, for example insulators wound from varnished or impregnated paper, and is concerned with providing means for conducting away capacity current from such insulators more especially for draining the high-frequency current occurring under surge conditions.

In high-voltage insulators having embedded stress-grading layers, it is customary to provide an earthed metallic layer or other member at or near the outside of the insulator, suitably formed to act as a shield preventing glow discharge between the insulator and external metal parts, for example the flange by which the insulator may be mounted on the apparatus with which it is associated. The earthed metallic member is usually the outer stress-grading layer of the insulator and the provision of the connection for earthing it presents certain difficulties. If the layer is of comparatively stout metal foil it is difficult to avoid the formation of voids between the foil and the insulating material and these voids result in harmful internal discharges usually accompanied by hissing. This can be avoided by employing materials capable of better adhesion, such as metallised paper, metal-sprayed paper, graphite-coated paper, or the like, but the current carrying capacity of these materials is very small and may be insufficient to withstand the fairly substantial high-frequency current that tends to be produced under surge conditions, and hence may result in burning out of the material round the junction between the layer and its connection to the earthed flange.

According to the present invention an electric insulator of the kind described includes conducting layers embedded in the insulating material whereof at least one layer is required to have an external connection applied to it, for example for draining capacity current, and whereof one or more layers are stress-grading layers of thin conducting material and at least one layer is a surge-draining layer of stouter conducting material to which the external connection is applied and which is arranged so that the whole or the major part of the layer is shielded by the adjacent stress-grading layer or layers, the latter stress-grading layer or layers and the related surge-draining layer being interconnected by a path or paths of conducting material for draining the normal capacity current, but so arranged that for draining high-frequency surge current there is a path between them which is distributed over the whole or a major part of the surface of the stress-grading layer and which is of such impedance that a substantial proportion of the high-frequency surge current takes this distributed path. Whilst normally the arrangement would be such that the majority of the current would take the distributed path in some instances the conducting connection may suffice to carry the majority of the current, the distributed path being relied on only to make up a small fraction of the total.

Preferably the distributed path for the high-frequency surge currents is constituted so that its impedance under high-frequency surge conditions is less than it is under normal conditions.

For example the distributed path for the high-frequency surge current may conveniently be afforded by the capacity between the two layers in which case the surge-draining layer will be of such shape and so disposed that the capacity between it and the adjacent stress-grading layer is substantial and, in addition, will be connected to it by a conductor or conducting circuit of high impedance. Usually the surge-draining layer is of substantially the same length as the adjacent stress-grading layer although in some instances the former might be only of three-quarters or even half the length of the latter. Again in some instances the surge-draining layer may be slightly longer than the adjacent stress-grading layer.

The invention may be carried into effect in various ways but certain specific embodiments thereof will now be described by way of example with reference to the accompanying diagrammatic drawings, in which

Figure 1 is a diagrammatic axial section of a bushing insulator, and

Figures 2–7 are diagrams of modified arrangements.

In the arrangement shown in Figure 1 a central conductor A is surrounded by insulating material B such as paper impregnated with synthetic resin wound to the form of a laminated tubular insulator. During the winding a number of stress-grading condenser layers C of thin conducting material are included at appropriate diameters.

Thereafter a surge-draining layer D of stouter conducting material, which may be perforated to improve adhesion, is embedded in the insulator and finally the insulator is encircled by an earthed member E such as the flange by which it is mounted on the apparatus with which it is associated. The outermost stress-grading layer is connected to the surge-draining layer by a high impedance connection F and serves to screen the surge-draining layer. The surge-draining layer is connected by means of a direct low-impedance connection G to the flange E which in turn is provided with an earthing connection H.

The effect of the arrangement is to avoid discharges under normal conditions even though the surge-draining layer may be of thick material of relatively poor adhesive quality since the adjacent stress-grading layer shields it from the electric field. For the same reason the adhesive used for the surge-draining layer need not necessarily possess good electrical characteristics.

Thus at normal frequency the surge-draining layer has very little effect since it is at substantially the same potential as the adjacent stress-grading layer. The ordinary capacity current of the insulator flows finally to earth through the conducting connection, and since the current is quite small it is readily carried thereby. Under surge conditions the current is greater but is of higher frequency. In these circumstances the capacity reactance between the surge-draining layer and the adjacent stress-grading layer decreases considerably whilst the impedance of the conducting connection remains constant or, if the connection is inductive, increases. Thus a substantial proportion of the current flows through the capacity between the two layers and is equally distributed along them, thereby reducing the flow of current along the thin layer to a safe value and avoiding all overloading of the layer near the junction with the connection, so preventing the burning out that has hitherto been a difficulty. In other words, the disposal of the layers is such that the current-carrying capacity of the thicker surge-draining layer is made use of when required and neither discharge nor burning out will occur.

In some cases the surge-draining layer may be divided into a number of sections, for example as shown in Figure 2 it may comprise three tubular sections D^1, D^2 and D^3 each constituting a portion of the length of the layer. The layers of insulation on opposite sides of the surge-draining layer can then be bonded together in the spaces between the sections. In some cases certain of the sections D^1, D^2 and D^3 may be of slightly different diameters in order further to minimise the weakening effect of a continuous line of poor adhesion. A similar effect may be obtained by forming the surge-draining layer with perforations.

The electrical connection between the two layers may be made in various ways but conveniently it is made by a metallic strip wound in contact with the stress-grading layer and gradually brought out during the winding process until it makes contact with the surge-draining layer. This strip should be of relatively high impedance, its inductance being appreciable by reason of its coiled form whilst its resistance may be increased by making it partly or wholly of suitable high-resistance material.

Where the surge-draining layer and adjacent stress-grading layer are very close together, as may be desirable to increase their capacity, there may be insufficient space for a connection of the required impedance to be wound between them. In this case as shown in Figure 3 the surge-draining layer may be in two sections D^4 and D^5 and a high-impedance connection F^1 may be wound out in the space between the sections and connected to the earthed flange E, to which the sections are also directly connected by direct contions G^1.

Alternatively, a connection may be brought straight out from each of the two layers and an external impedance F^4 may be connected between these two connections as seen in Figure 5. This impedance may take the form of, or may include, a coil for operating some device. Again, as shown in Figure 6, connections may be brought from each of the layers to points in the body of the insulator and an impedance F^5 may be wound into the material and connected between them.

Instead of relying solely on a capacity path for draining the high-frequency surge currents a distributed resistance path may be provided instead of or in addition to a localised conducting connection F, by rendering the material of the insulator B' between the layers sufficiently conducting, as seen in Figure 7.

Alternatively a material may be used which has a negative voltage coefficient of resistance so that with the increased voltage associated with surge conditions its impedance drops. Alternatively the dielectric between the layers may be treated in a suitable way with a material such as graphite either providing sufficient conductivity through the laminations to afford a path for the surge currents or providing sufficient surface conductivity to afford a conducting connection of spiral form. Combinations of these arrangements may be employed for example relying partly on a distributed conducting path and partly on a capacity path to pass the surge currents.

The surge-draining layer may be of metal foil, fine-mesh gauze or other suitable material and may or may not be embedded. If it is not embedded it may consist of a conducting tube round the body of the insulator with the flange fixed solidly to it. Again, the insulator may be reinforced mechanically by binding wire wound round it, and this may be arranged to act as the surge-draining layer.

Where the capacity between the two layers is relied on it should be as high as possible, and this capacity may be increased by suitable selection of materials for the part of the insulator between these two layers only.

Although the invention has been described as applied to the outer stress-grading layer of an insulator, it is also applicable to the inner stress-grading layer. It is known to connect the inner stress-grading layer to the central conductor, and it is usual to make this layer of substantial metal foil and to provide a low-impedance connection. As shown in Figure 4 the invention may be applied by making the inner stress-grading layer of easily adhering material and providing an additional stouter layer D^6 of metal foil nearer to the central conductor, connecting the two layers together by a high-impedance connection F^2 and providing a direct low-impedance connection G^2 from the foil layer.

Again, the invention is applicable to an intermediate layer of the insulator, for example where it is required to provide a current tapping in the insulator to obtain a reduced voltage for operating metering devices or the like. Figure 4 also includes such an arrangement in which what has been described as a surge-draining layer is of comparatively stout foil D^7 embedded in the insulator and is shielded from the field by a stress-grading layer or by two stress-grading layers one inside and the other outside it. The surge-draining layer D^7 is then connected to each of these stress-grading layers by a conducting path F^3 of comparatively high impedance. Clearly an insulator may be provided with an outer layer, an inner layer and one or more intermediate layers (as shown in Figure 4) or with any combination of these, arranged in accordance with the invention.

The invention has been described in connection with a construction in which the central conductor is the main power conductor through which the current flows, but it will be appreciated that it may be a conductor through which no current flows.

In some cases the conductor itself may be used as the surge-draining layer, provided the adjacent stress-grading layer is of easily adhering material, the connection is of high impedance, and the capacity is high.

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

1. An electric insulator including at least one stress-grading layer of thin conducting material embedded in the insulating material and a surge-draining layer also embedded in the insulating material and formed of stouter conducting material to which an external connection is made for draining capacity current and which is arranged so as to be shielded by at least one adjacent stress-grading layer, a path of conducting material interconnecting the latter stress-grading layer and the surge-draining layer for draining the normal capacity current, and a path between the said layers for draining high-frequency surge current which path is distributed over at least a major part of the surface of the stress-grading layer and is of such impedance that a substantial proportion of the high-frequency surge current takes this distributed path.

2. An electric insulator including at least one stress-grading layer of thin conducting material embedded in the insulating material and a surge-draining layer also embedded in the insulating material and formed of stouter conducting material to which an external connection is made for draining capacity current and which is arranged so as to be shielded by at least one adjacent stress-grading layer, a path of conducting material interconnecting the latter stress-grading layer and the surge-draining layer for draining the normal capacity current, and a path between the said layers for draining high-frequency surge current which path is distributed over at least a major part of the surface of the stress-grading layer and of which the impedance under high-frequency surge conditions is less than it is under normal conditions and is such that a substantial proportion of the high-frequency surge current takes this distributed path.

3. An electric insulator including at least one stress-grading layer of thin conducting material embedded in the insulating material, a surge-draining layer also embedded in the insulating material and formed of stouter conducting material arranged so that it is shielded by at least one adjacent stress-grading layer and the capacity between it and the latter is substantial, an external connection to the surge-draining layer for draining capacity current, and a high-impedance path of conducting material interconnecting the surge-draining layer and the said adjacent stress-grading layer for draining the normal capacity current, the impedance of the said path in relation to the capacity between the layers being such that a substantial proportion of the high-frequency surge current is passed by the capacity.

4. An electric insulator including at least one stress-grading layer of thin conducting material embedded in the insulating material and a surge-draining layer of stouter conducting material to which an external connection is made for draining capacity current and which is arranged so as to be shielded by at least one adjacent stress-grading layer, the insulating material between the latter stress-grading layer and the surge-draining layer being rendered sufficiently conducting to drain the normal capacity current, and providing a path for draining high-frequency surge current which path is distributed over at least a major part of the surface of the stress-grading layer.

5. An electric insulator including at least one stress-grading layer of thin conducting material embedded in the insulating material and a surge-draining layer of stouter conducting material to which an external connection is made for draining capacity current and which is arranged so as to be shielded by at least one adjacent stress-grading layer, the material of the insulator between the latter stress-grading layer and the surge-draining layer having a negative voltage coefficient of resistance and affording a conducting path for draining the normal capacity current, and a path between the said layers for draining high-frequency surge current which path is distributed over at least a major part of the surface of the stress-grading layer.

6. An electric insulator including at least one stress-grading layer of thin conducting material embedded in the insulating material and a surge-draining layer also embedded in the insulating material and formed of stouter conducting material to which an external connection is made for draining capacity current and which is arranged so as to be shielded by at least one adjacent stress-grading layer and is of substantially the same length as the latter, a path of conducting material interconnecting the latter stress-grading layer and the surge-draining layer for draining the normal capacity current, and a path between the said layers for draining high-frequency surge current which path is distributed over at least a major part of the surface of the stress-grading layer and which is of such impedance that a substantial proportion of the high-frequency surge current takes this distributed path.

7. An electric tubular wound insulator including at least one stress-grading layer of thin conducting material embedded in the insulating material and a surge-draining layer of stouter conducting material to which an external connection is made for draining capacity current and which is arranged so as to be shielded by at least one adjacent stress-grading layer, a conductor wound between the layers of insulating material to form a path interconnecting the latter stress-grading layer and the surge-draining layer for draining the normal capacity current, and a path between the said layers for draining high-frequency surge current which path is distributed over at least a major part of the surface of the stress-grading layer and which is of such impedance that a substantial proportion of the high-frequency surge current takes this distributed path.

8. An electric tubular wound insulator including at least one stress-grading layer of thin conducting material embedded in the insulator and a surge-draining layer also embedded in the insulator and formed in at least two circumferentially divided sections of stouter conducting material to which an external connection is made

for draining capacity current and which is arranged so as to be shielded by at least one adjacent stress-grading layer, a path of conducting material interconnecting the latter stress-grading layer and the surge-draining layer for draining the normal capacity current, and a path between the said layers for draining high-frequency surge current which path is distributed over at least a major part of the surface of the stress-grading layer and which is of such impedance that a substantial proportion of the high-frequency surge current takes this distributed path.

9. An electric tubular wound insulator including at least one stress-grading layer of thin conducting material embedded in the insulator and a surge-draining layer also embedded in the insulator and formed in at least two circumferentially divided sections of different diameters of stouter conducting material to which an external connection is made for draining capacity current and which is arranged so as to be shielded by at least one adjacent stress-grading layer, a path of conducting material interconnecting the latter stress-grading layer and the surge-draining layer for draining the normal capacity current, and a path between the said layers for draining high-frequency surge current which path is distributed over at least a major part of the surface of the stress-grading layer and which is of such impedance that a substantial proportion of the high-frequency surge current takes this distributed path.

10. An electric tubular wound insulator including at least one stress-grading layer of thin conducting material embedded in the insulating material, a surge-draining layer of stouter conducting material arranged so that it is shielded by at least one adjacent stress-grading layer and the capacity between it and the latter is substantial, an external connection to the surge-draining layer for draining capacity current, and a conductor wound between the layers of insulating material to form a high-impedance path interconnecting the surge-draining layer and the said adjacent stress-grading layer for draining the normal capacity current, the impedance of the said path in relation to the capacity between the layers being such that a substantial proportion of the high-frequency surge current is passed by the capacity.

11. An electric tubular wound insulator including at least one stress-grading layer of thin conducting material embedded in the insulator, a surge-draining layer also embedded in the insulator and formed in at least two circumferentially divided sections of stouter conducting material arranged so that it is shielded by at least one adjacent stress-grading layer and the capacity between it and the latter is substantial, an external earthed member, a direct connection from the earthed member to the surge-draining layer for draining capacity current, and a high-impedance path of conducting material connecting the said adjacent stress-grading layer to the earthed member through the space between sections of the surge-draining layer for draining the normal capacity current, the impedance of the said path in relation to the capacity between the layers being such that a substantial proportion of the high-frequency surge current is passed by the capacity.

12. An electric tubular insulator including a central conductor surrounded by insulating material, at least one stress-grading layer of thin conducting material embedded in the insulating material, a surge-draining layer also embedded in the insulating material and formed of stouter conducting material arranged so that it is shielded from the central conductor by at least one adjacent stress-grading layer and the capacity between it and the latter is substantial, an external connection to the surge-draining layer for draining capacity current, and a high-impedance path of conducting material interconnecting the surge-draining layer and the said adjacent stress-grading layer for draining the normal capacity current, the impedance of the said path in relation to the capacity between the layers being such that a substantial proportion of the high-frequency surge current is passed by the capacity.

13. An electric insulator including at least one stress-grading layer of thin conducting material embedded in the insulating material, a surge-draining layer also embedded in the insulating material and formed of stouter conducting material having apertures in it to improve adhesion between the insulating material on opposite sides of it and arranged so that it is shielded by at least one adjacent stress-grading layer and the capacity between it and the latter is substantial, an external connection to the surge-draining layer for draining capacity current, and a high-impedance path of conducting material interconnecting the surge-draining layer and the said adjacent stress-grading layer for draining the normal capacity current, the impedance of the said path in relation to the capacity between the layers being such that a substantial proportion of the high-frequency surge current is passed by the capacity.

14. An electric insulator including at least one stress-grading layer of thin conducting material embedded in the insulating material, a surge-draining layer of stouter conducting material arranged outside the outermost stress-grading layer so that it is shielded by the latter and the capacity between it and the latter is substantial, an external connection to the surge-draining layer for draining capacity current, and a high-impedance path of conducting material interconnecting the surge-draining layer and the said adjacent stress-grading layer for draining the normal capacity current, the impedance of the said path in relation to the capacity between the layers being such that a substantial proportion of the high-frequency surge current is passed by the capacity.

15. An electric insulator including at least one stress-grading layer of thin conducting material embedded in the insulating material, a surge-draining layer of stouter conducting material arranged inside the innermost stress-grading layer so that it is shielded by the latter and the capacity between it and the latter is substantial, an external connection to the surge-draining layer for draining capacity current, and a high-impedance path of conducting material interconnecting the surge-draining layer and the said adjacent stress-grading layer for draining the normal capacity current, the impedance of the said path in relation to the capacity between the layers being such that a substantial proportion of the high-frequency surge current is passed by the capacity.

16. An electric insulator including at least two stress-grading layers of thin conducting material embedded in the insulating material, a surge-draining layer of stouter conducting material arranged outside at least one stress-grading layer and inside at least one other such layer so that

it is shielded by the adjacent stress-grading layers and the capacity between it and the latter is substantial, an external connection to the surge-draining layer for draining capacity current, and a high-impedance path of conducting material interconnecting the surge-draining layer and each of the said adjacent stress-grading layers for draining the normal capacity current, the impedance of the said paths in relation to the capacity between the layers being such that a substantial proportion of the high-frequency surge current is passed by the capacity.

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