

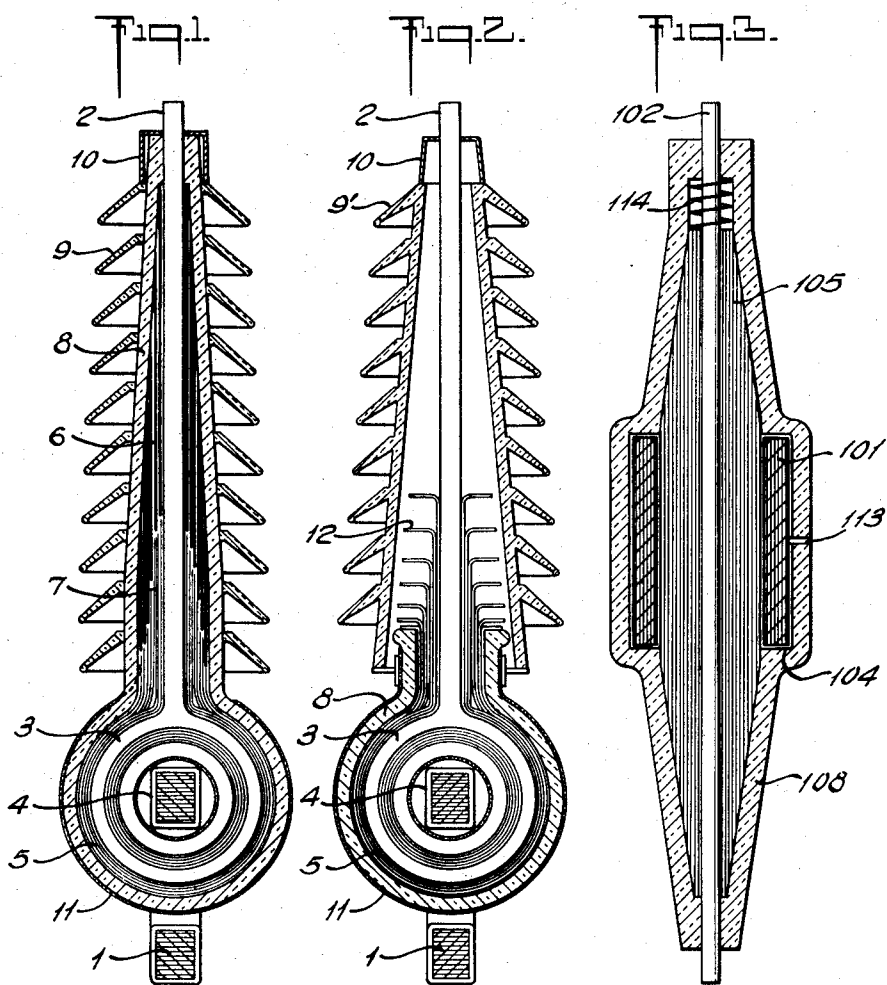
July 19, 1960

A. IMHOF
HIGH VOLTAGE INSULATOR

2,945,912

Filed June 14, 1954

2 Sheets-Sheet 1



July 19, 1960

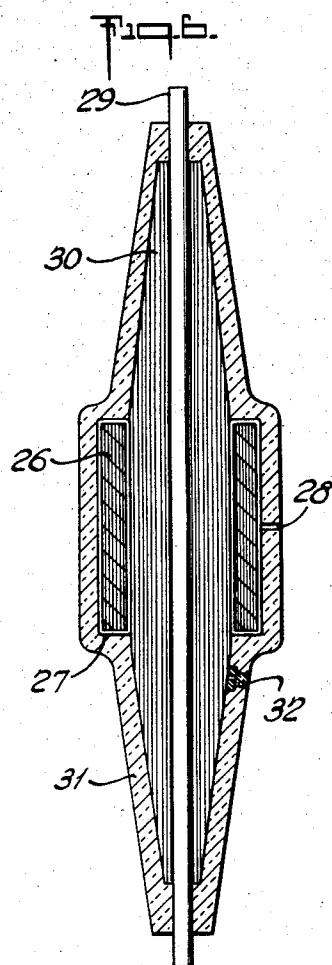
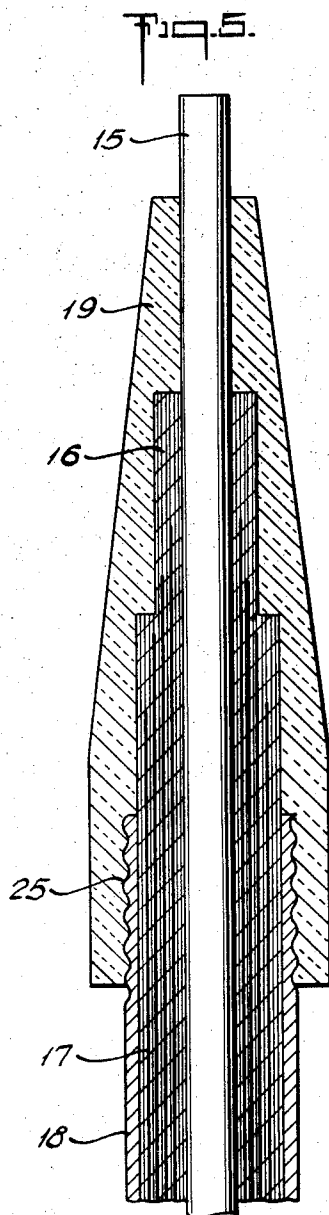
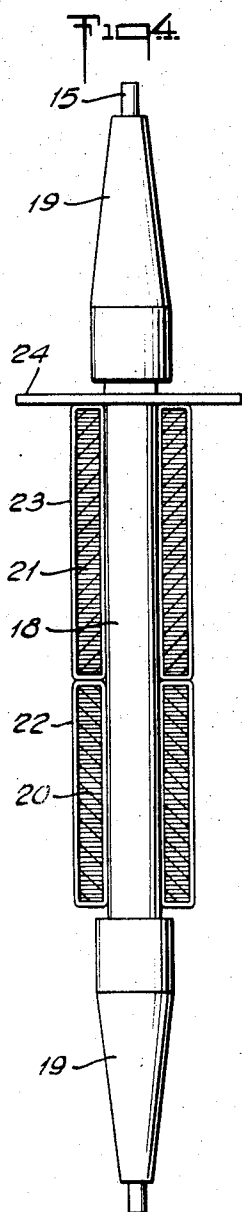
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HIGH VOLTAGE INSULATOR

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Filed June 14, 1954, Ser. No. 436,656

Claims priority, application Switzerland June 15, 1953

11 Claims. (Cl. 174—30)

The present invention relates to high voltage insulators consisting at least partly of synthetic resins and a method for manufacturing same, and more particularly to high voltage insulators for electrical apparatuses such as transformers, coupling condensers, dry rectifiers, and the like.

It is an object of the present invention to overcome the disadvantages of the high voltage insulators hitherto known in the art which are explained hereinafter.

An embedding insulation by means of cast resins may prove difficult, particularly in connection with very high voltages of the electrodes to be insulated. For instance, the casting of large objects is difficult owing to the contraction of the resin due to hardening and subsequent cooling, and owing to the thermal expansion due to fluctuations of the operating temperature. If the thermal expansion of the resin exceeds that of the metal forming the electrodes, the resin is likely to crack and break. Furthermore, the dissipation factor ($\tan \delta$) of the known embedding casting resins is so high at the high operating voltages that it is sometimes difficult to avoid thermal break-down of the resin.

On the other hand, insulators consisting of a wound web of fabric are easily damaged. If the webs of fabric are impregnated with a liquid such as oil they have to be protected against the loss of the liquid by being placed inside a container where they may gradually absorb moisture from the liquid. However, suitably chosen insulators consisting of wound webs of fabric have great advantages such as extremely high breakdown voltages, a low $\tan \delta$ and a high elasticity, so that they are very suitable for the embedding of field controlling coverings, wire coils, and the like.

The invention overcomes the disadvantages set forth hereinabove in a simple manner by providing a combined high voltage insulating covering comprising a dielectric series connection of at least one layer of a wound web of insulating fabric and a layer of casting resin enclosing the same which is at least partly under electrical stress. In this series connection of the two dielectrics the embedding resin forms at least the outermost layer, and, therefore, a container for the wound dielectric. The connection combines essentially the advantages of the two dielectrics without their disadvantages.

The casting resin must not be porous, and since it has to take up a portion of the total voltage drop, it must have a dielectrically good quality. Preferably such casting resins are suitable which are obtained by a poly-reaction such as a polymerization of polyaddition, from starting materials which are liquid at room temperature or increased temperatures, particularly from castable materials which harden without splitting off any volatile components.

According to the invention, the wound insulating webs or bands consist preferably of a porous dielectric such as paper, impregnated with an insulating liquid. In order to take full advantage of the high dielectric strength of such wound bands, the specific dielectric resistance

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thereof should be as large as possible, which is accomplished by using impregnating liquids having a small dielectric constant, such as mineral oils having a dielectric constant of 2.3 to 2.5, or liquid fluorinated hydrocarbons, e.g. tri-perfluoro-butyl-t-amine having a dielectric constant of 1.86.

It is well known in the art that laminated paper insulators have a dielectric strength which may be much higher than that of a layer of compressed gas having the same dimensions, provided that a certain ratio of the pressure to the thickness of the layer is maintained. Particularly advantageous is the thus obtainable high shock voltage strength which, independently of the pressure and the thickness of the layer, is higher than that of the corresponding gaseous dielectric.

According to an embodiment of the invention, the dielectric strength of the laminated paper dielectric is further improved by permeating the paper web with a gas or a mixture of gases.

In some cases it may be useful to put the gas under such a high pressure that the dielectric strength of the paper insulation permeated by a compressed gas is higher than that of the same paper insulation permeated by air under equal pressure and temperature conditions.

Suitable gases are, for instance, gaseous halogens either by themselves or as components of a gas mixture. However, also other gases may be used such as compressed air, nitrogen, carbon dioxide under normal or elevated pressure, inert gases, or mixtures of air and gases containing chlorine and/or fluorine, furthermore chlorophenyl indane with or without pressure. Gas pressures from 1 to approximately 25 atmospheres may be used.

The gas permeated paper band may be obtained by placing first the insulating bandage, then casting and hardening through the synthetic resin layer under vacuum whereupon the apparatus is filled with the gas or gas mixture. The gas may be supplied, for instance, by means of a valve arranged in the wall of the cast resin, said valve being connected with a container containing the gas under pressure; if desired, the valve may be plugged by casting resin after the apparatus has been filled with gas. The filling with compressed gas may be accomplished, for instance, by means of a small rubber plate cast into the resin wall; for filling the evacuated apparatus, said rubber plate is perforated by a hollow needle connected to a container of compressed gas. Later the perforation together with the rubber plate can be closed by casting thereinto the same resin as used for the wall.

For preparing the insulation according to the invention it is of advantage to wind the bandage as a first step, then to place the element in a casting mold, and thereafter to pour the resinous raw material into the mold. After hardening of the resinous enclosing body, the bandaged insulation is dried under vacuum; for this purpose, openings may be provided, if required, in the resinous body. Then the impregnating step is carried out.

The danger of inflammation which is greater under similar conditions with insulating liquids than with insulating solids, is largely diminished by the enclosure consisting of the solid body of synthetic resin. However, in order to eliminate this danger even when the resin enclosure is split open, insulating liquids are used which are incombustible or at least as heat resistant as the casting resin itself. Such liquids are, for instance, certain fluoroethers, fluoro-amines, and fluoro-silicones. In order to prevent bursting of the casting resin enclosure when overheated during operation, I use preferably liquid materials having a boiling point as high as possible, preferably exceeding 150° C., such as tri-perfluorohexyl-t-amine or tri-perfluorobutyl-t-amine.

If, for particularly heat-resistant insulators, casting

resins are used which have a high heat resistivity, also the wound insulation consists preferably of a heat resistant material, for instance asbestos band or glass fiber band. This is particularly to be recommended when such insulators are provided with wire turns or windings which are heated by the operating current.

In some cases, for instance for high frequency currents, the wound insulation may consist also of non-porous thermoplastic materials such as polystyrene, polyethylene, tetrafluoroethylene and fluorochloroethylene polymers, polyvinyl chloride, polyvinylidene chloride, and others. The low heat resistivity of some of these materials does not preclude their application since also enclosing casting resins are available which have a low hardening temperature. Such non-porous foils may be wetted with a liquid dielectric so that they do not enclose any air between the turns after the winding thereof, e.g. polystyrene may be wetted with mineral oil.

Another insulating material suitable for windings, which offers advantages in certain cases, is a flexible band rich in mica, consisting e.g. of super-imposed layers of mica splittings assembled with thin coatings of insulating binder between each layer.

The combination of insulators according to the invention may be applied with advantage also in cases where a field control by conductive inserts, or an arrangement of wire turns such as those met in primary windings of voltage transformers, is desired. Conductive inserts, for instance in the shape of metal foils, may be readily wrapped in during the winding of the insulating bandage. Normally the ends of the controlling insert are arranged inside the wound insulating web (for instance paper web).

Laminated insulators present on the one hand the advantage that their electric strength perpendicularly to the laminated layers is very high; on the other hand, however, they have the disadvantage that the electric strength in the direction of the laminated layers is much smaller. At the border of such capacitive control inserts steep field gradients occur, particularly in the direction of the laminated layers. According to the invention this disadvantage is overcome in a simple manner by embedding the ends of the control inserts in the enveloping layer of casting resin. This affords also the possibility to provide the ends with a bulge diminishing the field gradient; the bulge is embedded into the casting resin.

The insulation according to the invention is furthermore applicable to condenser leads having one end under oil, the control inserts of which reach as far as the outer surface lying under oil, and which follow one another in radial direction so closely that a high voltage gradient is tolerated. Such a fine control may be accomplished according to the invention by maintaining the control inserts in the correct mutual position by the wound dielectric and leading them up to the surface through the enveloping layer of casting resin.

In order to reduce the amount of expensive liquid dielectrics used for impregnating the laminated dielectric, the latter extends advantageously in axial direction of the leading-in insulators only as far as required by the field strength.

When it is a question of accommodating the wire turns, for instance, in voltage or current transformers, the wire turns may be preferably located in a free space left between the wound insulation and the enveloping insulation consisting of cast resin.

Elongated bodies, particularly elongated leading-in insulators may be subject to the difficulty that the resin cover breaks due to the shrinkage at the hardening and cooling thereof. In order to overcome this drawback, a weak spot advantageously designed as a groove, is provided according to the invention in a zone in which the resin cover is subject to a relatively slight electrical stress so that the resin cover splits in said zone when,

under the influence of contractile forces, the insulator is cooled. Then the joint is again cemented in a separate operation by casting resin.

It is also possible to make elongated bodies such as leading-in insulators by casting each of the ends by itself and forming the intermediate part of the leading-in insulator by a metal tube.

The invention will now be described more in detail with reference to the accompanying drawings, showing, by way of example, some embodiments of the present invention. In the drawings:

Fig. 1 is a sectional elevation of a first embodiment of the invention in form of a current transformer for high voltages;

Fig. 2 is a sectional elevation of a second embodiment of the invention with a current transformer of similar design;

Fig. 3 is a sectional elevation of a third embodiment of the invention showing a current transformer the primary of which is formed by a rod;

Fig. 4 is an elevation, partly in section, of an elongated leading-in rod current transformer with two secondary windings;

Fig. 5 is a section, on an enlarged scale, of the upper end of the transformer shown in Fig. 4; and

Fig. 6 is a sectional elevation of a modification of the embodiment shown in Fig. 3.

Referring now to the drawings and first to Fig. 1, a magnetic annular core 1 is penetrated by a tube 3 containing the primary windings (not shown) and being provided with a tubular extension or stem 2 which contains the current leads (not shown) connected to the primary winding (not shown). The secondary winding 4 surrounds the core 1.

The primary winding (not shown) is wrapped by the insulating paper band 5 extending partly also over the stem 2. This part of the insulating paper band includes potential control inserts 6 arranged coaxially with the stem 2 and having lower terminations 7. The insulating paper band 5 is arranged inside the insulation 8 consisting of a cast resin and provided with weather protecting sheaths 9, for instance consisting of porcelain, and with a cover piece 10. The insulation 8 of cast resin is provided with a grounded conductive outer layer 11 extending substantially over the lower part of the insulation 8 carrying the core 1.

The operation of this device is the same as that of any insulator provided with a current transformer.

The current transformer shown in Fig. 2 is similarly designed. However, the paper insulation 5 ends in umbrella-like parts 12. The space between the ceramic insulating mantle 9' and the paper insulation 5 is filled with an insulating liquid (not shown).

Referring now to Fig. 3 of the drawings, a hollow iron core 101 is passed through by a primary conductor 102 shaped as a rod and surrounded by the secondary winding 104 which leads to the terminals such as 113. The paper insulation 105 encloses part of the rod-like primary conductor 102. The resinous body 108 enclosing the whole structure except the ends of the primary conductor 102 is electrically stressed only at the two conical end portions thereof. The secondary winding 104 wound on the magnetic core 101 is in direct contact with the mid portion of the paper insulation 105. An expanding body 114, for instance a helical spring, is arranged between the one end face of the paper insulation 105 and the resin body 108. If the magnetic core 101 is provided with, or replaced by, a grounded part, the apparatus described hereinbefore may be used as a high voltage leading-in insulator.

Referring now to Figs. 4 and 5 of the drawings, the high voltage current conductor 15 is closely surrounded over part of its length by an impregnated paper insulation 16 provided with condenser control insets 17. The paper insulation 16 is enclosed in its middle portion by a metal

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tube 18, and at the ends thereof by a synthetic resin insulation 19 cast thereon. The metal tube 18 is surrounded by ferromagnetic cores 20, 21, carrying, respectively, the secondary windings 22 and 23 of the current transformers. A plate 24 serves for attaching the cores and the secondaries of the transformer to the metal tube 18. Preferably the part of the metal 18 surrounded by the cast resin 19 is provided at the outside thereof with grooves 25 improving the mechanical connection and the sealing of the parts 18 and 19.

It has proved to be advantageous to place the paper band under a radial pressure being higher than the pressure obtainable by the winding operation. In this way, the dielectric strength of the wound bands is increased in the direction of the axis. The described and shown embodiments show a cover about the wound bands which is so formed that the above condition for the radial pressure is satisfied. A still higher electrical strength in radial and axial directions is furthermore obtained by subjecting the impregnating liquid to a pressure exceeding the atmospheric pressure.

The two measures for increasing the electrical strength may be applied in combination, thus achieving a further increase of the electrical strength.

Referring now to Fig. 6 of the drawings showing a rod-shaped current transformer in section, the ferromagnetic annular core 26 is surrounded by the secondary winding 27 which leads to the terminals such as 28. The high voltage current rod or bar 29 penetrates the core 26 and is insulated against the same by the wound paper insulation 30 permeated by gas and surrounded by the synthetic resin body 31 enclosing also the core 26 carrying the secondary winding 27. A valve 32 arranged in the wall of the synthetic resin body 31 serves for conducting the gas to the wound paper insulation 30.

Having thus described the invention and the advantages thereof, it will be understood that the invention is not to be limited to the details herein disclosed, otherwise than set forth in the appended claims.

I claim:

1. A multiple insulation for a high voltage current conductor comprising an oil impregnated insulating fibrous web surrounding said conductor, a metal sleeve enclosing part of said web, and a sleeve consisting substantially of a casting resin, said resin sleeve enclosing said metal sleeve and said insulating web projecting from said metal sleeve and being integrally united with said metal sleeve and web.

2. An insulator as claimed in claim 1, including an electrically conductive winding arranged within said wound insulating web.

3. An insulator as claimed in claim 1, including an electrically conductive winding arranged between said

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wound insulating web and said sleeve of casting resin.

4. An insulator as claimed in claim 1, including a cushion of resilient material provided in an area being under a low electrical stress.

5. An insulator as claimed in claim 1, wherein said layer of casting resin encloses only partly said wound insulating web and defines a free portion thereof, comprising a metal part covering said free portion and engaging said layer of casting resin.

6. An insulator as claimed in claim 5, wherein said metal part is under a radial pressure exceeding the pressure caused by the winding of said web.

7. A multiple insulation for a high voltage current conductor comprising an insulating fibrous web surrounding a rod conductor, said web being impregnated with a dielectric, and a sleeve consisting substantially of a casting resin, said resin sleeve enclosing, and being integrally united with, said insulating web and extending beyond said web into intimate contact with said conductor.

8. An insulator as claimed in claim 7 wherein said wound insulating web consists of gas-filled paper.

9. An insulator as claimed in claim 8 wherein said gas-filled web has a dielectric strength higher than the dielectric strength of corresponding air-filled web under equal pressure and temperature conditions.

10. An insulator as claimed in claim 8, wherein the pores of said web are filled with halogen.

11. A method of manufacturing a high voltage insulator comprising the steps of making a bandaged insulator, casting an insulator consisting of synthetic resin around said bandaged insulator, providing a weak zone in said cast insulator, hardening said cast insulator, allowing said weak zone to break under the influence of contracting stresses, closing said break, and impregnating said bandaged insulator with a fluid insulator.

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