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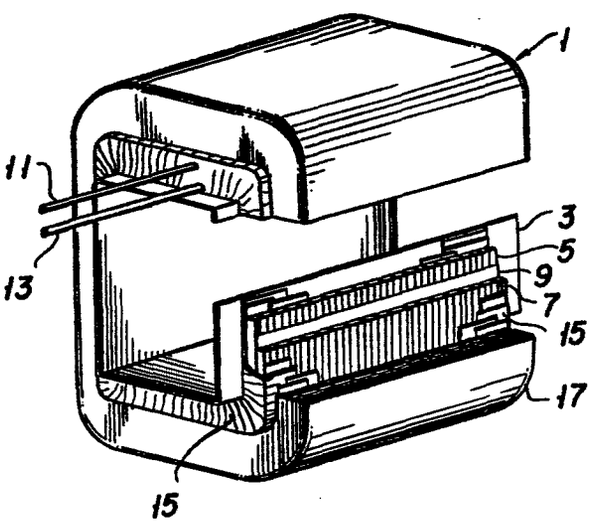
(54) High voltage transformer and method.

(57) A high voltage transformer includes a gas permeable crepe paper envelope (15, 27) wrapped around the transformer windings (5, 7, 21). The windings and crepe paper envelope are encapsulated in a gas impermeable material (31) using standard resin casting techniques and then impregnated with gaseous SF_6 (35) which is a self-healing dielectric gas. The crepe paper envelope prevents the resin coating material from penetrating the windings, thus allowing better diffusion and contact of the dielectric gas with the windings.



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HIGH VOLTAGE TRANSFORMER AND METHOD

Background of the Invention

Field of the Invention

The present invention relates to electrical transformers and, more particularly, to an arrangement for encapsulating and impregnating the electrical windings of a transformer with a dielectric gas.

Description of the Prior Art

Electrical transformers come in a wide variety of styles and voltage ratings. One type of transformer is used to convert medium-to-high voltages (e.g. several hundred to several thousand volts) carried by electrical transmission lines to relatively low voltages (e.g. a few hundred volts) for distribution to customers or for powering equipment.

Because of the high voltages present on the windings of such a transformer, micro-arcing may occur between the windings or other surrounding materials which can cause short circuits and early failure of the transformer.

One solution to this problem of micro-arcing has involved the use of a so-called "self healing" dielectric gas, such as sulfur hexafluoride (SF_6) which is used to impregnate the windings of the transformer. Such a gas has the property of rapidly recombining together even in the presence of an electrical arc that would otherwise tend to disassociate the molecules of the gas. This action of the gas acts to "quench" any such arcs before damage occurs to the transformer windings or other surrounding materials.

It has been the practice to encapsulate such transformers by applying a resin molding compound directly to the exterior portions of the electrical windings. The dielectric gas is then introduced into the spaces between the resin encapsulation material and the windings by means of a vacuum impregnation technique.

However, the foregoing arrangement has a serious disadvantage in that the resin encapsulation material, which is in direct contact with the transformer windings, can form voids or small sealed pockets around the windings into which the dielectric gas cannot reach. It has been found that these voids or pockets are sources of failure due to partial electrical discharges and arcing occurring between windings through these voids.

Summary of the Invention

It is a general object of the present invention to provide an improved electrical transformer or other electrical device having electrical windings and to provide a method of manufacture of said device.

This and other objects are attained, in accordance with one aspect of the invention by an electrical device having at least one set of electrical windings comprising at least one layer of a gas permeable and electrically insulating material disposed around the electrical windings; at least one layer of a gas impermeable and electrically insulating material disposed around the gas permeable material; and a dielectric gas disposed between the electrical windings and the gas impermeable layer and impregnating the gas permeable layer and electrical windings.

Another aspect of the invention includes a method of insulating an electrical device having at least one set of electrical windings comprising the steps of: (a) wrapping at least one layer of a gas permeable and electrically insulating material about the electrical windings; (b) forming at least one layer of a gas impermeable and electrically insulating material about the gas permeable material; and (c) impregnating the gas permeable layer and the windings with a dielectric gas.

Brief Description of the Drawing Figures

These and other features and advantages of the present invention will be apparent from the following detailed description of the preferred embodiment, when taken in conjunction with the appended drawing figures wherein:

Figure 1 is a cut-away perspective view of the secondary of a transformer constructed in accordance with the principles of the present invention prior to encapsulation; and

Figure 2 is a cut-away perspective view of a finished, encapsulated transformer formed in accordance with the principles of the present invention.

Detailed Description of the Preferred Embodiment

Figure 1 shows the secondary windings and associated components of a voltage transformer which is constructed in accordance with the principles of the present invention. Secondary windings unit 1 comprises a generally rectangular coil form 3 formed from an insulator, such as cardboard or plastic, about which is wound first and second windings 5 and 7, separated by a spacer 9, formed from paper. Windings 5 and 7 are formed from a continuous length of electrically conductive material, such as wire, and are connected to external devices (not shown) through secondary terminals 11 and 13.

As shown in Figure 1, a layer of a thin, flexible, gas permeable and electrically insulating material 15, such as crepe paper, is wrapped around at least a portion of secondary windings 5 and 7. While in Figure 1 the gas permeable material is shown as only covering a portion of the secondary windings, it will be understood that gas permeable material 15 may be wrapped so as to completely cover the exposed surfaces of windings 5 and 7.

Preferably, the gas permeable material used is an electrical grade crepe paper. Such a material has a dielectric strength in the range of 150 volts per mil thickness and a low ash content. Electrical grade crepe paper is preferred since it is inherently flexible and stretchable and thus will conform to any irregularities in the surface of the electrical windings and around any angles or bends that these windings make. The thickness and/or number of layers of the gas permeable material is empirically selected in accordance with the assumed maximum voltage which might be applied to the transformer windings. That is, the higher the voltage the transformer will be tested at, the thicker the crepe paper and/or the greater the number of layers employed.

It should also be noted that, at least for a lower voltage (e.g. 15 kilovolts or less) transformer, the gas permeable material is not spirally wound about the electrical windings, but rather is applied as a single piece which does not substantially overlap itself at any given point. This reduces the weight and bulk of the gas permeable material used, as compared to prior art arrangements where such material is wound about the secondaries in a spiral fashion. At higher voltages (e.g. above 15 kilovolts) one or more of the layers of gas permeable material may be wrapped and/or spirally wound about the transformer windings to increase the resultant dielectric strength of the wrapping.

A barrier 17 is disposed around the completed secondary windings unit. Barrier 17 is formed from an insulating material, such as kraft paper and serves to insulate the secondary windings unit from the primary windings which are subsequently formed around the secondary windings unit.

As shown in Figure 2, the primary windings unit 19 comprises a series of concentric electrical windings 21 wound about secondary windings unit 1. Primary windings 21 are connected to external devices through primary terminals 23 and 25.

A layer of gas permeable material 27, such as crepe paper, is wrapped about primary windings 21 in a fashion identical to that of the secondary windings unit 1. A layer of static shielding material 29, formed from a conductive or semiconductive material, such as copper mesh or metallized paper or plastic, is wound about the exterior of the primary windings unit 19.

After the secondary and primary windings units have been wrapped with the gas permeable material and assembled together as shown in Figure 2, a layer of a gas impermeable, moldable material is formed around the assembled secondary and primary windings units 1 and 19. Preferably, the gas impermeable material is an epoxy resin. This enables the assembled transformer to be encapsulated in a simple one-step resin casting process. Of course, other well-known types of plastic molding compounds could be used.

Prior to encapsulation with gas impermeable material 31, a one-way sealable valve 33 is arranged as shown in Figure 2 so as to enable the introduction of a dielectric gas 35 into the interior of the encapsulated transformer. The dielectric gas preferably is sulfur hexafluoride (SF_6) or diatomic nitrogen (N_2). Nitrogen may be used in transformers rated for up to 15 kilovolts, while sulfur hexafluoride may be used in transformers having higher and lower voltage ratings.

A particular advantage of such dielectric gases, and especially sulfur hexafluoride, is that they are "self-healing", i.e. even if disassociated due to the presence of an electrical arc, they quickly recombine and act to quench the arc and thereby prevent damage from occurring to the windings or adjacent structures. Such gases also have the advantage of having a higher dielectric strength than a vacuum or air. In particular, sulfur hexafluoride can have a dielectric strength of up to 10 times that of air and be approximately 100 times as effective as air in quenching an arc.

The gaseous dielectric 35, which is drawn into the interior of the encapsulated transformer using a vacuum impregnation technique,

diffuses through the gas permeable protective layers 15 and 27 and through and around the primary and secondary windings 21, 5 and 7. The use of a gas permeable material, such as crepe paper, as a protective layer around the primary and secondary windings insures that the gas impermeable material which encapsulates the transformer will not penetrate between the primary or secondary windings, and thereby prevents the formation of voids or air pockets in the gas impermeable material which heretofore have been known sources of failure, due to arcing between the windings through such voids.

The completed transformer includes a magnetic core unit 37, as shown in dashed outline in Figure 2.

Transformers constructed in accordance with the principles of the present invention show significantly better partial discharge characteristics (i.e. resistance to arcing between windings and associated components) than those not using a gas permeable protective layer. This results in a transformer which is less likely to fail under high applied voltages.

While the present invention has been described in considerable detail, it will be understood that various changes and modifications will occur to those skilled in the art. Thus while the present invention has been described with respect to the construction of a voltage transformer, the principles disclosed herein may be used with other types of transformers, such as current transformers, and for other types of devices using electrical windings, such as solenoids. Accordingly, the foregoing description of the preferred embodiment of the invention is intended to be merely illustrative, but not limitive, of the invention as defined by the claims.

What is claimed is:

1. An electrical device having at least one set of electrical windings characterized by:

at least one layer of a gas permeable and electrically insulating material disposed around the electrical windings;

at least one layer of a gas impermeable and electrically insulating material disposed around the gas permeable material; and

a dielectric gas disposed between the electrical windings and the gas impermeable layer and impregnating the gas permeable layer and electrical windings.

2. The device of claim 1 characterized in that the gas permeable material is an electrical grade crepe paper.

3. The device of claim 1 or 2 characterized in that at least one layer of the gas permeable material does not substantially overlap itself.

4. The device of claim 1, 2 or 3 characterized in that the gas impermeable material is a moldable material.

5. The device of claim 4 characterized in that the moldable material is an epoxy resin.

6. The device of any previous claim characterized by a sealable valve means disposed in the gas impermeable layer for introducing the dielectric gas into contact with the gas permeable material and electrical windings.

7. The device of any previous claim characterized in that the dielectric gas is diatomic nitrogen (N_2).

8. The device of any previous claim characterized in that the dielectric gas is sulfur hexafluoride (SF_6).

9. The device of any previous claim characterized in that the device is a transformer.

10. A method of insulating an electrical device having at least one set of electrical windings characterized by the steps of:

(a) wrapping at least one layer of a gas permeable and electrically insulating material about the electrical windings;

(b) forming at least one layer of a gas impermeable and electrically insulating material about the gas permeable material; and

(c) impregnating the gas permeable layer and the windings with a dielectric gas.

11. The method of claim 10 characterized in that the gas permeable material is an electrical grade crepe paper.

12. The method of claim 10 or 11 characterized in that the gas permeable material is wound so that it does not substantially overlap itself.

13. The method of claim 10, 11 or 12 characterized in that the gas impermeable layer is formed from a moldable material and is molded about the gas permeable layer to form a covering thereover.

14. The method of any one of claims 10-13 characterized in that the moldable material is an epoxy resin.

15. The method of any one of claims 10-14 characterized by the step of arranging sealable valve means in the gas impermeable layer to facilitate introduction of the dielectric gas into contact with the gas permeable layer and the electrical windings.

16. The method of any one of claims 10-15 characterized in that the dielectric gas is diatomic nitrogen (N_2).

17. The method of any one of claims 10-15 characterized in that the dielectric gas is sulfur hexafluoride (SF_6).

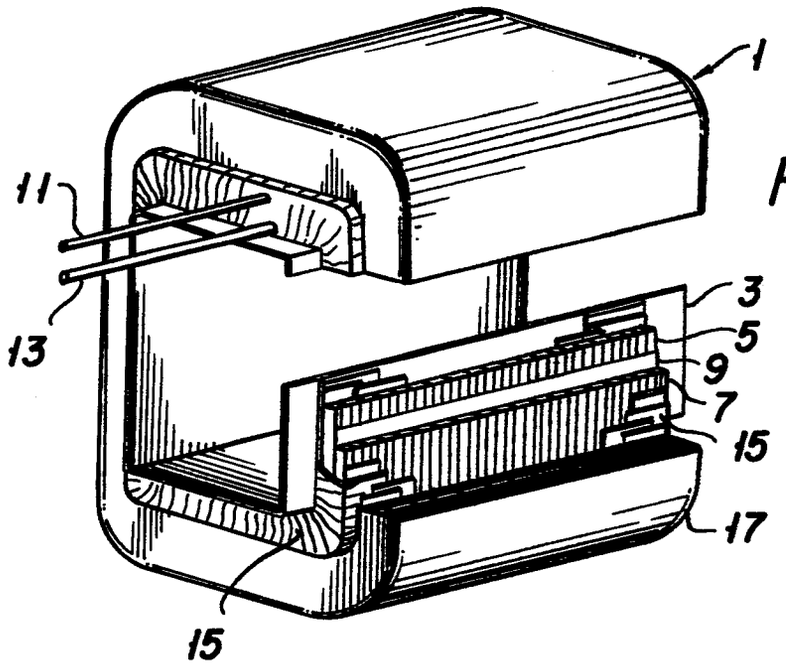

FIG.1

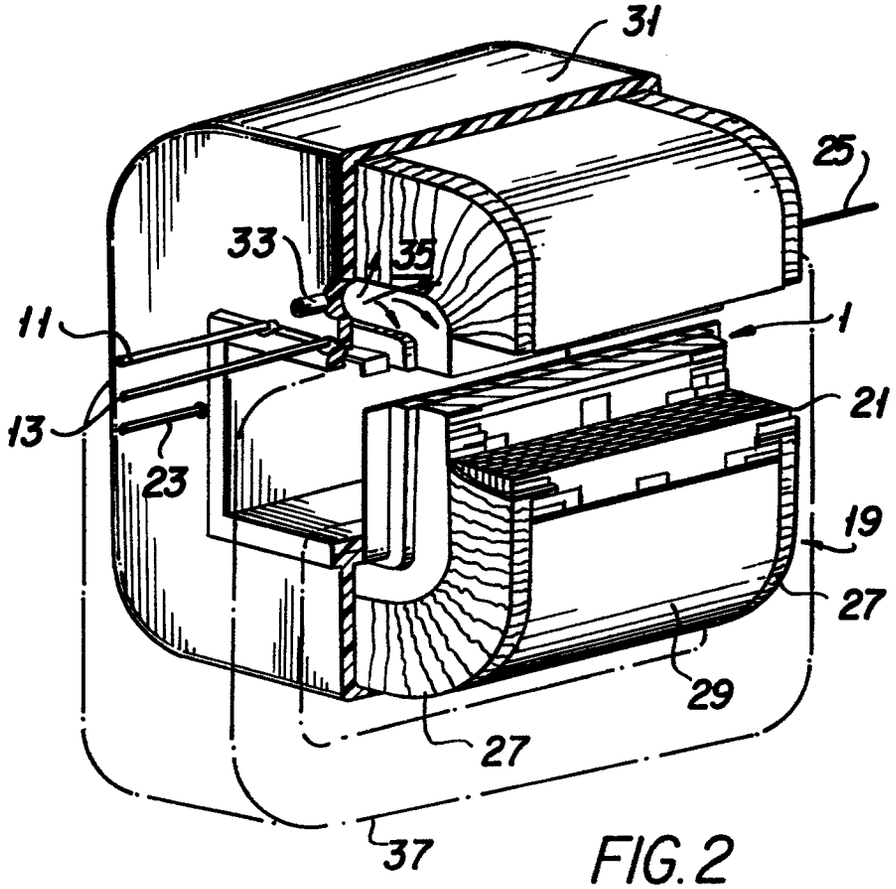

FIG.2

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EUROPEAN SEARCH REPORT

Application number

EP 86 40 0241

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
Y	US-A-3 233 311 (GENERAL ELECTRIC) * Column 4, line 68 - column 7, line 44 *	1	H 01 F 41/12
A		4-6,9, 10,13-15	

Y	PATENTS ABSTRACTS OF JAPAN, vol. 7, no. 292 (E-219) [1437], 27th December 1983; & JP - A - 58 166 704 (HITACHI SEISAKUSHO K.K.) 01-10-1983 * Whole document *	1	
A	Idem	4,6-8, 10,13, 15,17	TECHNICAL FIELDS SEARCHED (Int. Cl.4)
	---		H 01 F 41/00
A	US-A-3 868 766 (FORD MOTOR CO.) * Column 2, lines 26-40 *	2	

A	GB-A- 778 149 (MOSER-GLASER & CO.) * Page 1, lines 69-85 *	7,8,16 ,17	

A	US-A-2 893 061 (ALLIS-CHALMERS MANUFACTURING CO.)		
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	16-05-1986	VANHULLE R.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
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T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

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EUROPEAN SEARCH REPORT

Application number

EP 86 40 0241

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
A	PATENTS ABSTRACTS OF JAPAN, vol. 7, no. 13 (E-153) [1158], 19th January 1983; & JP - A - 57 170 509 (TOKYO SHIBAURA DENKI K.K.) 20-10-1982		
A	US-A-3 905 001 (MATSUSHITA)		
A	DE-B-1 072 748 (SIEMENS)		

TECHNICAL FIELDS SEARCHED (Int. Cl.4)

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	16-05-1986	VANHULLE R.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
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P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

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