

[54] **ELECTRICAL INDUCTIVE APPARATUS**
[75] Inventors: **Landis E. Feather**, Sharon, Pa.;
Louis Morris, Campbell, Ohio
[73] Assignee: **Westinghouse Electric Corporation**,
Pittsburgh, Pa.
[22] Filed: **Aug. 9, 1971**
[21] Appl. No.: **170,005**
[52] U.S. Cl. **336/60, 336/198**
[51] Int. Cl. **H01f 27/08**
[58] Field of Search.....336/60, 205, 55, 198, 208;
310/65; 174/143, 15 C

[56] **References Cited**

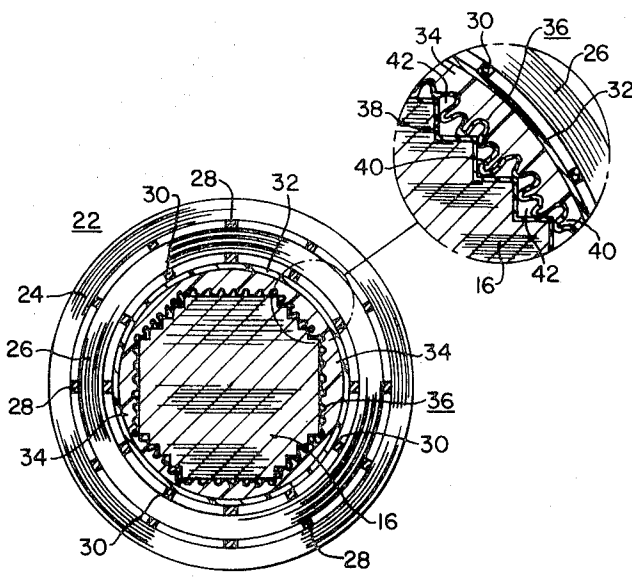
UNITED STATES PATENTS			
1,360,752	11/1920	Johannesen	336/60
3,138,773	6/1964	Nichols et al.	336/205
3,568,118	3/1971	Kuriyama et al.	336/60
3,431,524	3/1969	Droverman	336/60
3,151,304	9/1964	Miller	336/60 X
3,331,910	7/1967	Grimmer	174/143 X

FOREIGN PATENTS OR APPLICATIONS
512,761 2/1939 Great Britain.....336/60
233,608 11/1959 Australia174/15 C
1,074,801 7/1967 Great Britain.....336/60

Primary Examiner—Thomas J. Kozma
Attorney—A. T. Stratton et al.

[57] **ABSTRACT**
An arrangement for supporting a winding tube of a power transformer. The winding tube is supported and held in position by a supporting structure constructed of rigid plastic foam. Spaces or openings in the supporting structure, which are created by suitably shaped members, permit the liquid dielectric of the transformer to flow through the supporting structure to cool adjacent structures. The suitably shaped members are inserted between the winding tube and its supporting member before the plastic foam is placed therein, thereby defining the shape of the spaces or openings in the supporting structure.

18 Claims, 6 Drawing Figures



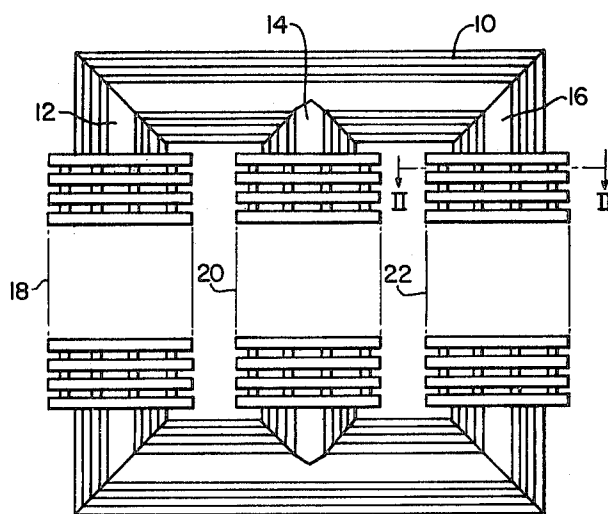


FIG. 1.

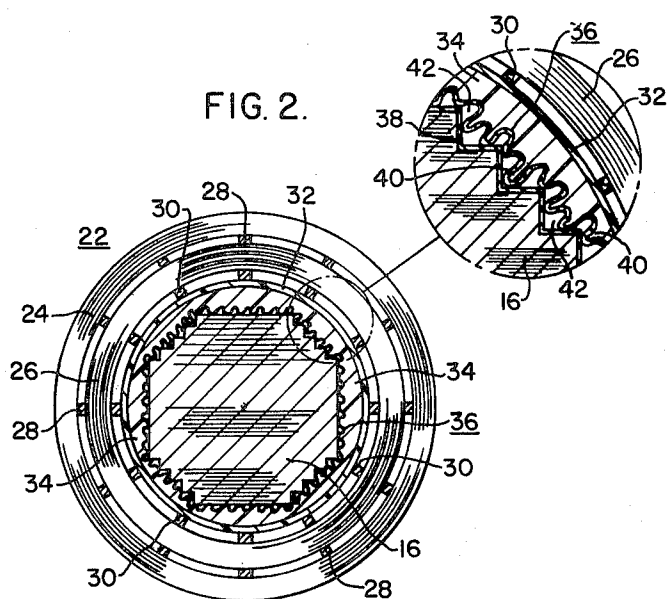


FIG. 2.

FIG. 3.

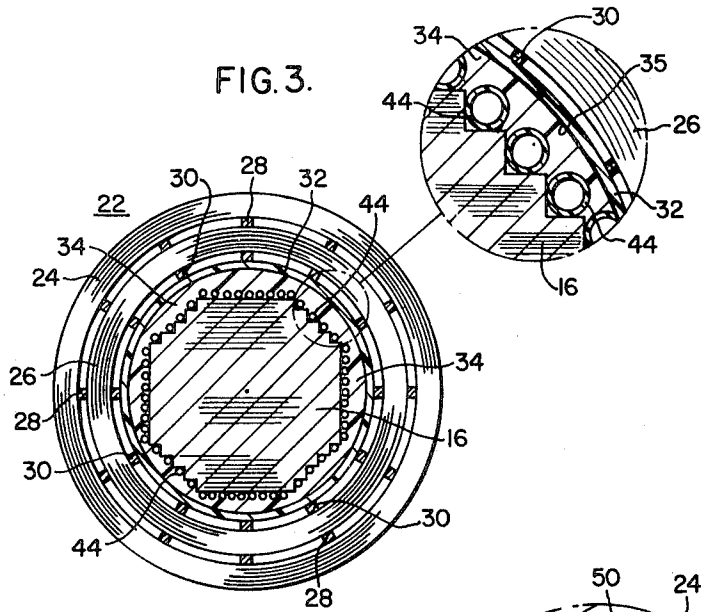
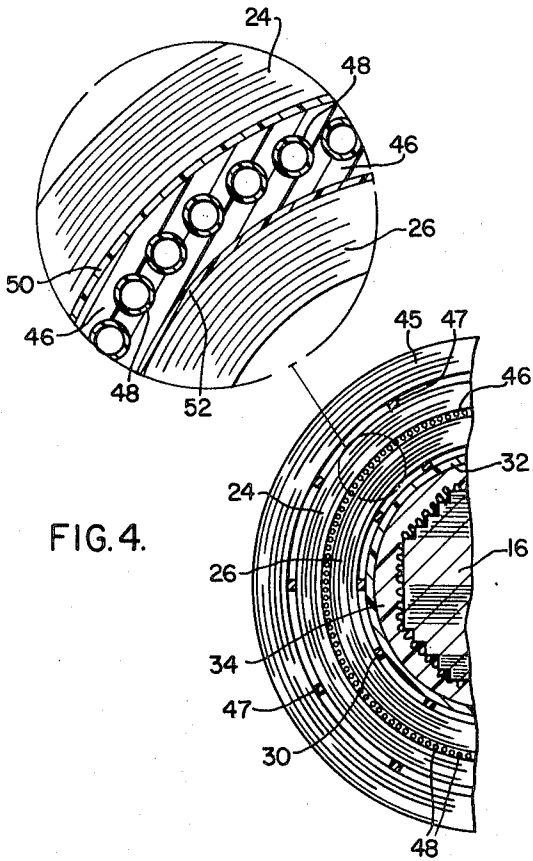


FIG. 4.

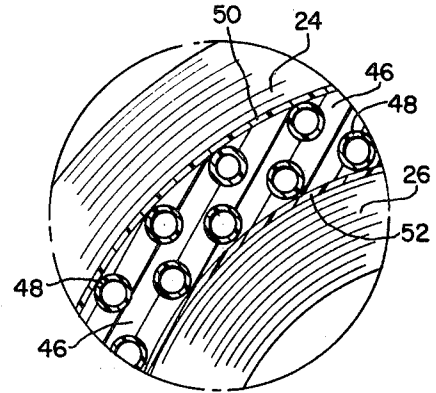


FIG. 5.

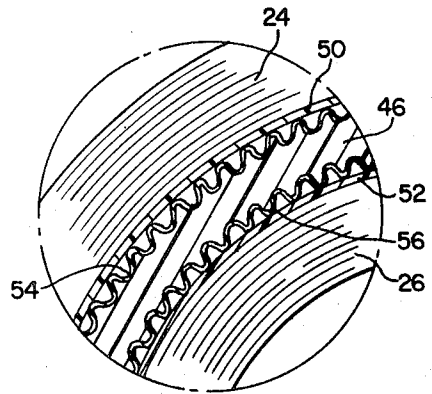


FIG. 6.

ELECTRICAL INDUCTIVE APPARATUS

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates, in general, to electrical inductive apparatus and, more specifically, to insulating and supporting means for the windings of core-form transformers.

2. Description of the Prior Art

The construction of core-form transformers takes into consideration certain aspects of the electrical and mechanical performance of the transformer. The metallic laminations which form the magnetic core of the transformer must be mechanically held together for proper operation of the transformer. The most common method presently used includes the use of bolts which are inserted through holes in the laminations. While this provides sufficient mechanical strength, the electrical performance of the transformer suffers due to the core losses caused by the holes in the laminations.

It is also a requirement in power transformers that the magnetic core be cooled as effectively as possible. This is accomplished in liquid cooled power transformers by circulating the liquid dielectric, which is usually mineral insulating oil, along the surfaces of the core. This makes it necessary to provide a space or channel between the core and the winding positioned thereon to allow the flow of oil adjacent to the core. Since the innermost winding is subjected to inward forces during short circuits which tend to collapse the winding, there must be a compromise between rigid supporting members and cooling channels adjacent to the core.

Generally, the innermost winding is first wound on a rigid insulating tube, then the tube and the winding assembly is slipped over the magnetic core. The tube is blocked to the core by inserting spacer sticks or rods between the core and the tube. This arrangement is undesirable for several reasons. The winding tube must be sufficiently thick to provide adequate mechanical support between spacer rod support points. As a result, the winding tube must be thicker than required by electrical considerations. It also positions the winding farther from the core than is electrically required.

The use of spacer rods also results in inadequately supported winding tubes. Due to variations in core width, spacer diameter, and winding tube size, some spacers may not completely fill the gap between the core and the tube, thus, the winding tube may be subjected to additional flexural stresses under short circuit conditions. To permit assembly when tolerances tend to reduce the gap, the tube is normally fitted loosely, which adds to the possibility of mechanical deformation of the winding tube. The spacer rod arrangement is very time consuming to assemble and there is a substantial possibility of damage to the tube when the rods are driven between the tube and the core.

Therefore, it is desirable and it is an object of this invention, to provide an economical, efficient, and satisfactory arrangement for supporting the windings of a power transformer.

SUMMARY OF THE INVENTION

The invention disclosed herein provides a new and useful arrangement for supporting a winding tube of a

power transformer which may be economically constructed and which performs efficiently. Suitably shaped spacing members are inserted in the region between the winding tube and the structure from which it is supported, such as the magnetic core. Plastic foam is then placed into the region and allowed to solidify, thus forming a supporting structure. The spaces provided by the spacing members allow the liquid dielectric of the transformer to flow through the supporting structure and conduct heat away from adjacent structures.

This arrangement permits the use of a winding tube having a smaller wall thickness than permitted by prior art arrangements since the winding tube is supported continuously around its circumference. Since the plastic foam conforms to the size and shape of the winding tube, all areas of the winding tube are sufficiently supported. Because of the ability of the foam to compensate for manufacturing tolerances, the winding tube is always solidly supported. Additionally, since the winding tube does not have to be oversized to allow for tolerances, the winding thereon is consistently closer to the magnetic core when the arrangement taught by this invention is used. The fact that the supporting structure surrounds the magnetic core, and provides securing means therefor, allows modification of the conventional bolt arrangement for holding the laminations together. The elimination of some or all of the lamination bolts improves the efficiency of the transformer.

BRIEF DESCRIPTION OF THE DRAWINGS

Further advantages and usages of this invention will become more apparent when considered in view of the following detailed description and drawings, in which:

FIG. 1 is an elevational view of a core-form transformer constructed according to the teachings of this invention;

FIG. 2 is a cross-sectional view of the winding structure taken along the line II—II of FIG. 1 and constructed according to the teachings of an embodiment of this invention;

FIG. 3 is a cross-sectional view of a winding structure constructed according to the teachings of another embodiment of this invention;

FIG. 4 is a partial cross-sectional view of a winding structure illustrating an embodiment of this invention wherein the windings are separated by a supporting structure;

FIG. 5 is an enlarged partial cross-sectional view illustrating a supporting structure arrangement which is located between the windings and constructed according to the teachings of an embodiment of this invention; and

FIG. 6 is an enlarged partial cross-sectional view illustrating a supporting structure arrangement which is located between the windings and constructed according to the teachings of another embodiment of this invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Throughout the following description, similar reference characters refer to similar members in all figures of the drawings.

Referring now to the drawings, and FIG. 1 in particular, there is shown a laminated magnetic core 10 of a transformer constructed according to the teachings of this invention. The magnetic core 10 includes legs 12, 14 and 16 which have positioned thereon the winding structures 18, 20 and 22, respectively. The magnetic core 10 is constructed of layers of metallic laminations, with the width of the laminations varied to provide the pattern of a cruciform magnetic core. The winding structures 18, 20 and 22 are rigidly attached to their respective core legs by the arrangement hereinafter described in detail.

FIG. 2 is a cross-sectional view of the winding structure 22 taken along the line II—II of FIG. 1. The winding structure 22 includes an outer winding 24 and an inner winding 26. The windings are separated by the vertical spacers 28 which allow the liquid dielectric, which is not illustrated, to flow vertically between the windings 24 and 26. The vertical spacers 30 are positioned between the inner winding 26 and the winding tube 32 for a similar reason.

The winding tube 32 is supported from the magnetic core 16 by the supporting structure 34. The magnetic core 16 provides a mounting member for the winding tube 32. The inner boundary of the supporting structure 34 has a corrugated shape which provides channels through which the liquid dielectric may flow. The corrugated boundary of the supporting structure 34 is shown in more detail in the enlarged portion of FIG. 2. A boundary layer 36 defines the inner boundary of the supporting structure 34. The boundary layer 36 is constructed of a corrugated material which is faced on one side by the face member or spacer 38. The corrugated material of the boundary layer 36 comprises any suitable material, such as paper board. The face member 38 may be constructed of a similar material or it may be constructed of a material, such as polyethylene film, which will dissolve when exposed to the hot liquid dielectric of the transformer. This permits the dielectric to directly contact the magnetic core 16. The face member 38 should be thin for minimum resistance to heat transfer, while the boundary layer 36 should be reasonably stiff in order to prevent collapse of the corrugations during assembly. A paper material having a thickness of from 7 to 15 mils would be suitable composition for the boundary layer 36 material. The corrugations may be of coarse texture, such as the industry standard A fluting which is approximately $\frac{1}{4}$ inch high. A synthetic film or fibrous mat could also be used for the face member 38.

The supporting structure 34 is constructed of a suitable solid insulating material, such as rigid plastic foam. A polyurethane foam having a density of from 6 to 10 lbs. per cubic foot should be adequate for most applications, however, foams with densities between 2 and 30 lbs. per cubic foot could also be used depending on the strength required. Rigid plastic foams comprising epoxides, phenolics or silicones could also be used.

Constructing the structure illustrated in FIG. 2 may be accomplished by several different methods. One convenient method is to attach the single-faced corrugated structure, comprising the boundary layer 36 and the face member or spacer 38, to the magnetic core 16 with a suitable adhesive. The adhesive is placed between the magnetic core 16 and the face member or

spacer 38 and, since the boundary layer 36 is attached to the face member 38, the boundary 36 generally follows the contour of the magnetic core 16. The winding tube 32 is positioned around the magnetic core 16 and the bottom opening therebetween is blocked off. The plastic foam, in liquid form, is then injected into the region between the magnetic core 16 and the winding tube 32. The foam flows into the corrugations of the boundary layer 36 to provide radially extending ridges 40 which secure the supporting structure 34 to the magnetic core 16 when the foam expands and solidifies. The spaces 42, from which the foam has been restricted by the boundary layer 36, provide the cooling channels through which the liquid dielectric of the transformer may flow.

Other arrangements may be used to provide spaces in the supporting core 34 for dielectric flow. FIG. 3 illustrates an arrangement whereby hollow cylindrical tubes 44 are placed adjacent to the magnetic core 16 prior to the injection of the supporting structure 34 material into the region between the magnetic core 16 and the winding tube 32. The tubes 44 may be constructed of a suitable material, such as paper board, and left in position after the foam becomes rigid. The tubes 44 may be suitably constructed so that they can be removed after the foam becomes rigid. By using cylindrical tubes 44, spaces are created in the supporting structure 34 which permit the flow of dielectric therethrough to adequately cool the magnetic core 16. The diameter of the tubes may be varied to increase or decrease the cooling channel area, provided that a sufficient amount of the supporting structure 34 contacts the magnetic core 16 to adequately support the winding tube 32.

Due to the closed-cell gas-filled nature of the plastic foam material, corona may develop in the supporting structure 34 if the stress between the magnetic core 16 and the inner winding 26 is large enough. Corona discharges in the supporting structure 34 may be prevented by providing a grounded shield between the magnetic core 16 and the inner winding 26. Such a shield would be provided by the conductive coating 35 which is applied to the inner portion of the winding tube 32, with a suitable lead attached to the coating 35 and to a point at ground potential. Other shielding arrangements may be used to prevent corona discharges in the supporting structure 34.

The teachings of this invention may also be applied to the other regions of a transformer which require supporting means. In three-winding transformers, the middle winding tends to collapse under short circuit conditions. FIG. 4 illustrates an embodiment of this invention wherein a third winding 45 is positioned around the winding 24 with vertical spacers 47 therebetween. The winding 24 is supported from the winding 26 by the supporting structure 46 instead of using vertical spacers 28 as shown in FIGS. 2 and 3. The winding tube 50 and the insulating member 52 define the outer and inner boundaries, respectively, of the supporting structure 46. The insulating member 52, which provides a mounting member for the winding tube 50, may comprise the solid insulating material which is wrapped around the outside of the winding structure 26. The cylindrical tubes 48 are positioned in the supporting structure 46 to provide spaces for the flow of the liquid

dielectric. The composition of the tubes 48 may be similar to the composition of the tubes 44 shown in FIG. 2. The placement of the tubes, and the diameter thereof, is dependent upon the desired mechanical and thermal properties of the supporting structure 46. The tubes 48 shown in FIG. 4 are substantially equally spaced at the same radial distance throughout the supporting structure 46. Although not illustrated, additional channel space area may be obtained by making the outside diameter of the tube 48 substantially equal to the width of the supporting structure 46, that is, the radial distance between the insulating member 52 and the winding tube 50.

The tubes 48 may be radially staggered throughout the supporting structure 46, as shown in FIG. 5, in order to place the liquid dielectric channel spaces adjacent to the surfaces which require cooling. The arrangement shown in FIG. 5 uses the corrugated members 54 and 56 to provide the spaces in the supporting structure 46. Although FIG. 5 illustrates liquid dielectric spaces adjacent to the winding tube 50 and to the insulating member 52, it is within the teachings of this invention that liquid dielectric spaces may be provided at either the inner or outer boundary only. The boundary layers 54 and 56 may be constructed of a material similar to that used to construct the boundary layer 36 illustrated in FIG. 2. It is also within the contemplation of this invention that face members may be attached to the corrugated boundary layers 54 and 56 to aid in the application of the boundary layer to the winding tube 50 and to the insulating member 52.

There has been disclosed a new and useful arrangement for supporting a winding tube of a power transformer. The winding tube is secured in position by a supporting structure which has spaces therein to provide channels for the flow of liquid dielectric therethrough. Since numerous changes may be made in the above described apparatus and different embodiments of the invention may be made without departing from the spirit thereof, it is intended that all of the matter contained in the foregoing description or shown in the accompanying drawings shall be interpreted as illustrative rather than limiting.

We claim as our invention:

1. A transformer comprising a winding tube having a winding disposed thereon, a mounting member for said winding tube, a supporting structure constructed of a rigid plastic foam disposed between said winding tube and said mounting member, said supporting structure

having openings therethrough for providing channels through which liquid dielectric may flow.

2. The transformer of claim 1 wherein the mounting member comprises a leg of a magnetic core.

3. The transformer of claim 1 wherein the mounting member comprises solid insulating material wrapped around a winding structure.

4. The transformer of claim 1 wherein the rigid plastic foam is selected from the group consisting of epoxides, phenolics and silicones.

5. The transformer of claim 1 wherein the rigid plastic foam from which the supporting structure is constructed comprises rigid polyurethane foam.

6. The transformer of claim 1 wherein the openings in the supporting structure are cylindrically shaped.

7. The transformer of claim 6 wherein the openings in the supporting structure are defined by hollow cylindrical tubes.

8. The transformer of claim 6 wherein the cylindrically shaped openings are substantially equally spaced at the same radial distance through the supporting structure.

9. The transformer of claim 6 wherein the cylindrically shaped openings are positioned throughout the supporting structure in a radially staggered pattern.

10. The transformer of claim 1 wherein the openings in the supporting structure are formed by a corrugated boundary of the supporting structure.

11. The transformer of claim 10 wherein the corrugated boundary is defined by a boundary layer constructed of insulating material.

12. The transformer of claim 11 wherein the insulating material from which the boundary layer is constructed comprises paper board.

13. The transformer of claim 11 wherein a spacer is positioned between said mounting member and said boundary layer.

14. The transformer of claim 13 wherein the spacer and the boundary layer are constructed of similar materials.

15. The transformer of claim 13 wherein the spacer is constructed of a material which dissolves in the liquid dielectric of the transformer.

16. The transformer of claim 13 wherein said spacer is constructed of polyethylene film.

17. The transformer of claim 13 wherein said spacer is constructed of paper.

18. The transformer of claim 13 wherein said spacer is constructed of fibrous mat.

* * * * *