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White et al.

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[54] **EXPANDABLE COIL BRACING TUBES FOR ELECTRICAL INDUCTIVE APPARATUS**

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[52] **U.S. Cl.** **336/196**, 29/602, 29/609, 336/60, 336/210

[51] **Int. Cl.** **H01f 27/30**

[58] **Field of Search** 336/196, 197, 198, 210, 336/60, 219, 209, 185; 310/42; 29/421, 455

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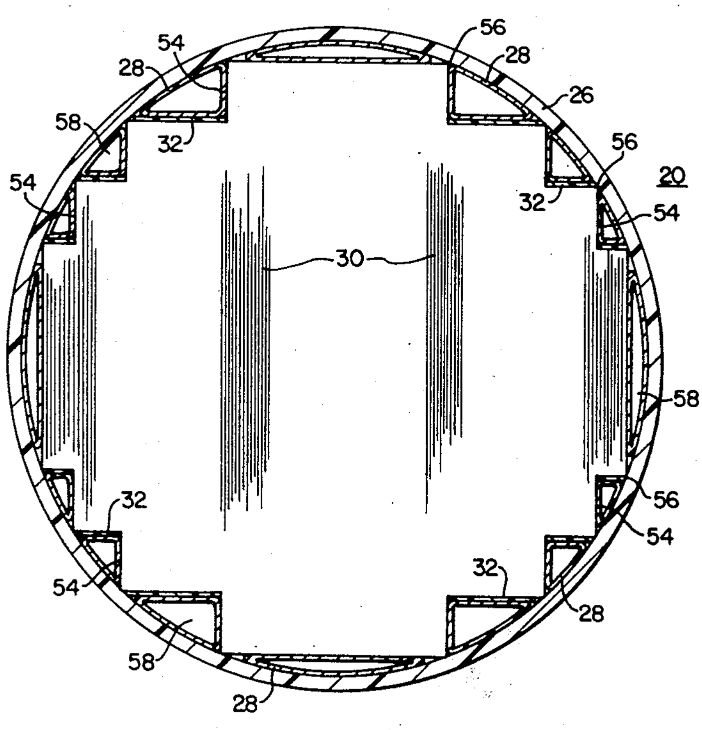
[57] **ABSTRACT**

A preshaped, hollow, expandable metal tube inserted between a magnetic core and a winding support tube in an electrical inductive apparatus. Expansion of the metal tube after it has been placed into position provides a tight fitting relationship between the magnetic core and the winding support tube, to prevent buckling of the winding support tube during short circuit conditions.

5 Claims, 4 Drawing Figures



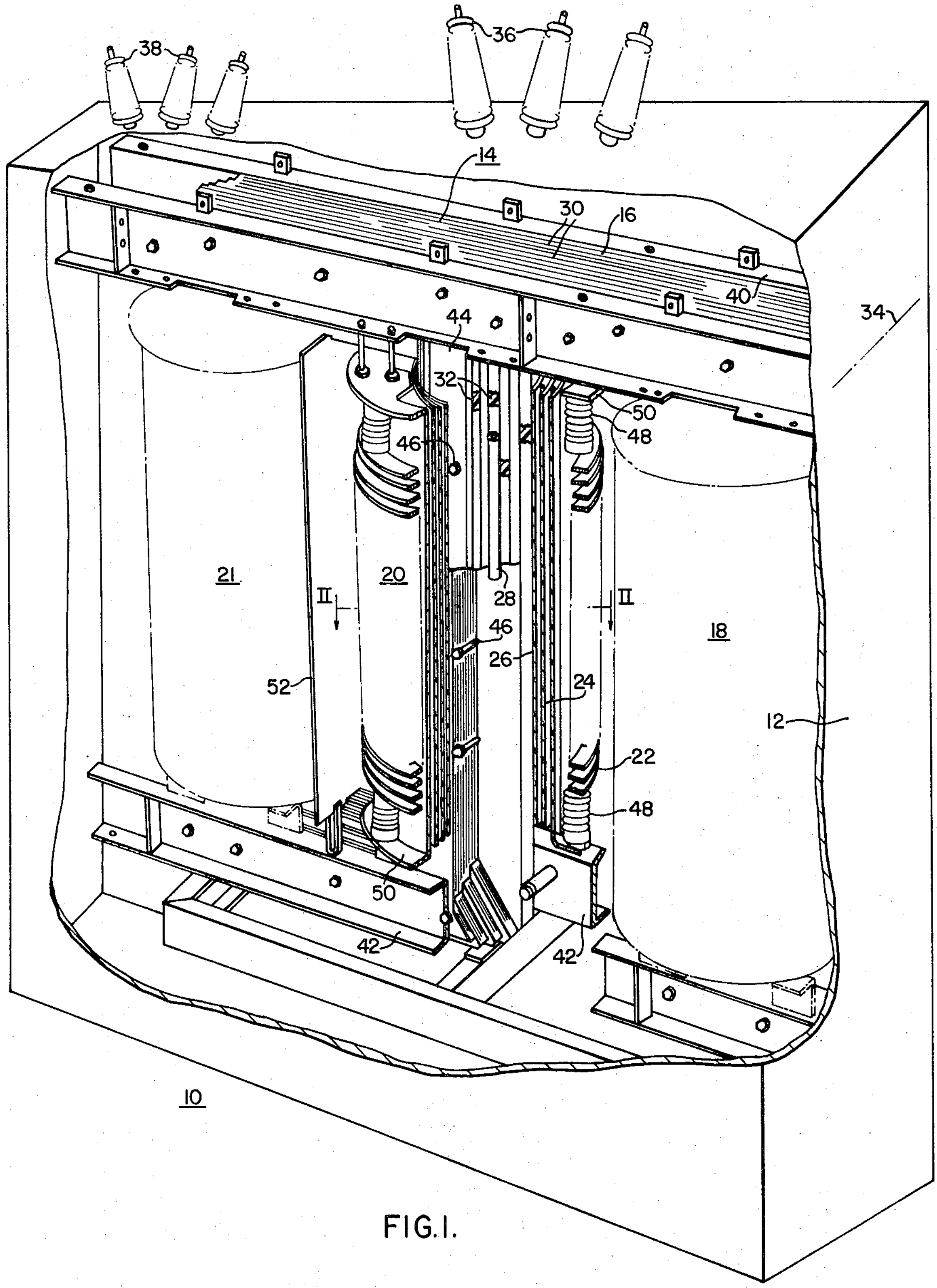

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FIG.1.

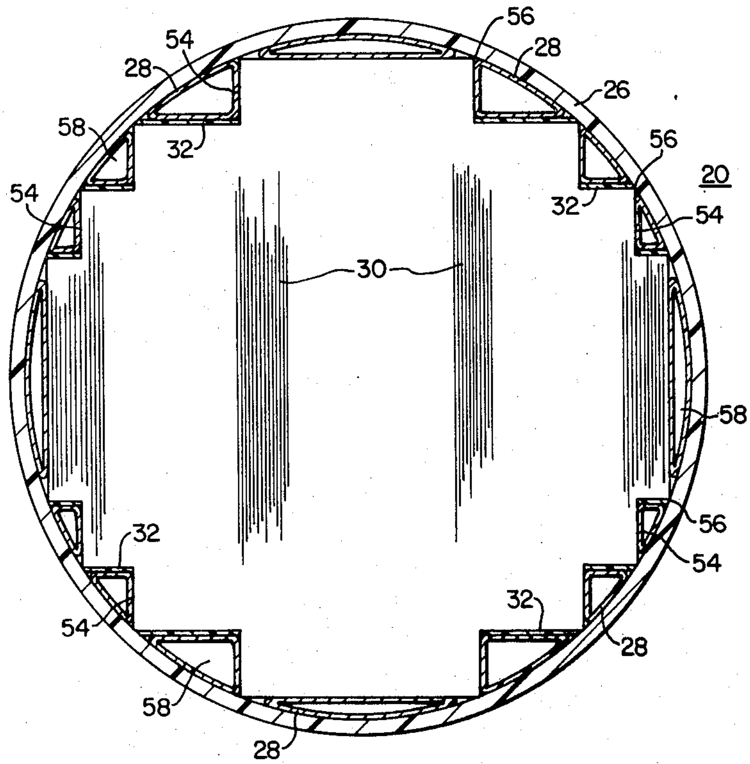

FIG. 2.

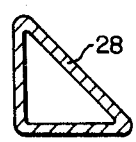

FIG. 3.

STACKING & SECURING METAL LAMINATIONS TO FORM A MAGNETIC CORE

↓

PROVIDING AN INSULATING MEMBER TO SURROUND THE MAGNETIC CORE

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DISPOSING A WINDING SUPPORT MEMBER TO AXIALLY SURROUND THE CORE

↓

PROVIDING A WINDING

↓

INSERTING A THIN WALLED, HOLLOW, ELONGATED, EXPANDABLE METAL TUBE

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EXPANDING THE METAL TUBE

↓

DISPOSING THE CORE WITHIN A CASING

FIG. 4.

EXPANDABLE COIL BRACING TUBES FOR ELECTRICAL INDUCTIVE APPARATUS

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to electrical inductive apparatus and more particularly to an improved method of fabricating and bracing the electrical inductive apparatus. Use of an expandable hollow metal tube which provides a tight fitting relationship after expansion between a magnetic core and a winding support tube makes fabrication of the electrical inductive apparatus easier and provides bracing to prevent buckling of the winding support tube when the electrical inductive apparatus undergoes a short circuit condition.

2. Description of the Prior Art

The present method of fabricating electrical inductive apparatus of the type described herein utilizes wooden dowels or glass spacers disposed between the magnetic core and the winding support tube on which the windings of the electrical inductive apparatus are placed. The purpose of the wooden dowels or the glass spacers is to prevent the collapse of the winding support tube against the magnetic core during a short circuit condition. As is known to those skilled in the art, there is great mechanical stress placed upon the windings and the core of an electrical inductive apparatus during a short circuit condition. In order to protect the windings and the magnetic core of the apparatus, support of the windings is required. However, the supports heretofore utilized have a variety of disadvantages.

When wooden dowels or glass spacers are used, the workman must select from approximately 9 sizes of dowels or spacers the one size which will fit the opening between the magnetic core and the winding support tube. Once the appropriate size of the dowel or spacer has been selected, the worker must stand on an elevated platform in order to reach the end of the dowel or spacer while driving it snugly into position between the core and the winding support tube. As the final dowels or spacers are driven into position, the first inserted dowels or spacers are frequently loosened, requiring the removal of the original dowel or spacer and the replacement thereof with a larger size. The wooden dowels must be processed before using to prevent shrinkage. Also, glass spacers are expensive to use.

It is evident, then, that the present method of fabricating an electrical inductive apparatus is time consuming and uneconomical. The proposed invention overcomes all of these above-mentioned disadvantages, and also provides a more rigid or tighter support for the winding support tube.

SUMMARY OF THE INVENTION

This invention utilizes a preshaped, hollow, expandable metal tube which can be easily placed into position between the magnetic core and a winding support tube of an electrical inductive apparatus, such as a transformer. After being placed in position between the winding support tube and the magnetic core, the metal tube is expanded by internal pressure until a tight fitting relationship between the magnetic core and the winding support tube is obtained. The internal pressure used to expand the metal tube can be obtained by hydraulic pressure, or other suitable means.

Because the metal tubes are expandable, fewer stock sizes are necessary than were required in the prior art. Also, since the metal tubes are expandable, selection of the proper size tube is not as difficult as required by the present method. Since the tubes do not require a tight fit before expansion, the need to drive them into place, and thus possibly damage the magnetic core of the transformer, is also eliminated. In addition, because a tight fit is not required before expansion, the need for the worker to stand on the elevated platform while installing the metal tubes, as required when using the wooden dowels or glass spacers, is also eliminated. The expandable metal tubes provide a more uniform fit over the entire axial length of the winding support tube, and there is less tendency for them to loosen as the final metal tubes are expnaded. The metal tubes require no initial processing to prevent shrinkage as is now required with a wooden dowel. Metal tubes are also more economical than the glass spacers now used in the art. The metal tubes are rigid enough to maintain a tight fit or bracing system between the magnetic core and the winding support tube after they have been expanded. The metal tubes, after expansion, do not distort or become loose due to short circuiting of the winding.

An object of the invention is to provide a method of fabrication for an electrical inductive apparatus, such as a transformer, utilizing a preshaped, hollow, expandable metal tube, which, after expansion, provides a tight fitting relationship between the magnetic core and the winding support tube of the transformer. It is desirable, and, it is a further object of this invention, to provide an economical, efficient, and satisfactory arrangement for supporting the winding tube of a transformer.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be more fully understood from the following detailed description of an illustrative embodiment taken in connection with the accompanying drawings, in which:

FIG. 1 is a perspective view of a core-form transformer, with portions removed for clarity, constructed according to the teachings of this invention;

FIG. 2 is a cross-sectional view of the magnetic core taken along section line II—II of FIG. 1;

FIG. 3 is a cross-sectional view of a preformed expandable metal tube used in the invention; and

FIG. 4 is a block diagram illustrating the steps comprising the method of fabrication of a transformer embodying the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Throughout the following description similar reference characters refer to similar elements in all figures of the drawing.

Referring now to the drawings, and FIG. **1** in particular, a perspective view of a power transformer **10** embodying the teachings of this invention is illustrated. Although the drawing illustrates a three phase power transformer, it is to be understood that this invention can be utilized on any core-form type transformer.

The transformer **10** comprises a casing **12** having a magnetic core **14** disposed within the casing **12.** The magnetic core **14** has a yoke portion **16,** a first leg **18,** a second leg **20** and a third leg **21.** Each of the legs **18, 20** and **21** of the magnetic core **14** is fitted with a winding assembly comprising a primary winding 22 and a secondary winding 24.

The high voltage or primary winding structure 22 and the low voltage or secondary winding structure 24 are concentrically arranged so as to axially surround each of the legs 18, 20 and 21 of the magnetic core 14. The low voltage or secondary winding structure 24 is disposed so as to be the inner of the winding structures and lies closest to the legs 18, 20 and 21 of the magnetic core 14. The high voltage or primary winding structure 22 is disposed so as to axially surround the low voltage or secondary winding structure 24. The high voltage or primary winding structure 22 comprises a plurality of radially disposed conductor turns which form an array of coil discs stacked in an axial direction. The low voltage or secondary winding structure 24 comprises a plurality of layers of strap conductor.

Referring specifically to the leg 20 of the magnetic core 14, which shows part of the winding structure cut away for clarity, a winding support member 26 axially surrounds the leg 20 of the magnetic core 14. Although reference is made to the leg 20, it is to be understood that the structure herein described applies to each leg 18, 20 and 21 of the transformer 10. As seen in the cut away portions of FIG. 1, the winding support member 26 is concentrically disposed about the leg 20 of the magnetic core 14 and extends axially between the leg 20 and the low voltage or secondary winding structure 24. The winding support member 26 is commonly a thin-walled, hollow, cylindrical tube fabricated from an insulating material, such as cardboard, and serves to support the low voltage or secondary winding structure 24 spaced slightly away from the leg 20 of the magnetic core 14.

An expandable metal tube 28 extends axially between the leg 20 of the magnetic core 14 and the winding support member 26. The expandable metal tube 28 is a thin-walled, hollow, elongated tube fabricated of low carbon steel approximately 0.030 inch thick. The expandable metal tube 28 is a peripherially closed member having an opening extending centrally and axially throughout its length.

The expandable metal tube 28 responds to an increase in pressure within it by expanding from a first preformed cross-section shape to an expanded second and different cross-section shape. When the expandable metal tube 28 has been expanded, in a manner to be described more fully herein, it simultaneously abuts, throughout its entire axial length, both the leg 20 of the magnetic core 14 and the inner surface of the winding support member 26. When in the expanded second cross-section shape, the expandable metal tube 28 provides a tight fitting relationship between the leg 20 of the magnetic core 14 and the winding support member 26. The expandable metal tube 28 braces the winding support member 26 against the leg 20 of the magnetic core 14 and prevents the collapse of the winding support member 26 when the winding support member 26 experiences the high mechanical stresses which occur during a short circuit condition on the windings. The expandable metal tube 28, when expanded to the second cross-section shape, will not collapse or change from this second cross-section shape under the high mechanical stresses which occur during a short circuit condition because the pressure exerted on the expandable metal tube 28 during the short circuit condition is less than the pressure required to expand the expandable metal tube 28 from the first preformed cross-section shape to the expanded second cross-section shape.

The magnetic core 14 is comprised of a plurality of metal laminations 30. The laminations 30 are stacked so that the core leg 18, the core leg 20, and the core leg 21 have a generally cruciform cross-section shape. The cruciform cross-section shape is obtained by stacking a predetermined number of individual laminations 30 in sections, the width of the laminations in each section decreasing as the outward distance from the center lamination section increases. The cruciform cross-section shape of the core leg 20 is best illustrated in FIG. 2.

The individual metal lamination 30 has a silicon coating which provides electrical insulation for the lamination. However, the laminations 30 have sheared edges which expose the steel which comprises the lamination. An insulating member 32 is therefore required from end to end of each core leg in order to prevent direct contact between the exposed edges of the metal laminations 30 and each of the expandable metal tubes 28. The insulating members 32 prevent direct contact between the exposed edges of the metal laminations 30 and the expandable metal tubes 28 when the expandable metal tubes 28 are in the expanded cross-section shape. The insulating members 32 prevent the expandable metal tubes 28 from short circuiting the laminations 30, and thereby prevents or reduces the flow of eddy currents in the laminations 30 and the expandable metal tubes 28.

The insulating members 32 may be sheets of nonconducting material, such as cardboard, wrapped around the legs of the magnetic core 14 in such a manner so that the interior surface of the cardboard sheet substantially contacts the entire axial surface of the core leg 20, the cardboard sheet thereby following the contour of the cruciform cross-section of the core leg. However, an alternative insulating coating of the silicone jelly or like material could be applied on the exposed edges of the metal laminations 30 to prevent direct contact between those edges and the expandable metal tubes 28.

A dielectric fluid 34, preferably oil, is contained within the casing 12 and completely surrounds the magnetic core 14, the high voltage or primary winding structure 22, and the low voltage or secondary winding structure 24. Since the expandable metal tubes 28 are hollow, when they are in the expanded second cross-section shape, the oil dielectric 34 fills the hollow, expandable metal tubes 28 and assists the cooling of the transformer 10.

The casing 12 has disposed thereon high voltage bushings 36 which provide electrical insulation for the electrical leads to the high voltage or primary winding structure 22. The casing 12 also has disposed thereon low voltage bushings 38 which provides electrical insulation for the electrical leads from the low voltage or secondary winding structure 24.

The metal laminations 30 which are stacked to form the magnetic core 14 are secured by a top end frame 40 and a bottom end frame 42. The laminations 30 are further secured by a first locking plate 44, a second locking plate (not shown) and a bolt 46 which extends through the first locking plate 44, through the metal laminations 30, and through the second locking plate. The high voltage or primary winding structure 22 is secured and compressed by a pressure block **48** and a pressure ring **50**. An insulating barrier **52** separates the leg **20** from each of the legs **18** and **21**.

Referring now to FIG. **2**, a cross-section view of the leg **20** of the magnetic core **14** taken along section line II—II of FIG. **1** is illustrated. In FIG. **2**, a more detailed view of the core leg **20** of the magnetic core **14** is shown. The magnetic core **14** is comprised of a plurality of metal laminations **30** which are disposed so as to provide the magnetic core **14** with a generally cruciform cross-section. The core leg **20** of the magnetic core **14** has a plurality of discrete stepped gradations **54** extending about its perimeter. Axially surrounding the core leg **20** of the magnetic core **14** is the winding support member **26**. The interior surface of the winding support member **26** comes in contact with the core leg **20** of the magnetic core **14** at a plurality of contact points illustrated by reference numeral **56**. The axial surfaces of the core leg **20** of the magnetic core **14** and the interior surface of the winding support member **26** define a plurality of void spaces **58** which extend axially between the core leg **20** of the magnetic core **14** and the winding support member **26**. The expandable metal tubes **28** are disposed so as to occupy each of the void spaces **58** which extend between the core leg **20** of the magnetic core **14** and the winding support member **26**. The expandable metal tubes **28** are inserted into the void spaces **58** that lie between the core leg **20** of the magnetic core **14** and the winding support member **26**. The expandable metal tubes **28** are stoppered at one end thereof and filled with a fluid medium in preparation for expansion. The expandable metal tubes **28** are then expanded from a first predetermined cross-section shape to an expanded section cross-section shape by applying pressure to the fluid medium within the expandable metal tubes **28**. After the expandable metal tubes **28** have been expanded, the stopper is removed and the fluid medium is withdrawn. While in the expanded second cross-section shape, the expandable metal tubes **28** simultaneously abut the interior surface of the winding support member **26** and the leg **20** of the magnetic core **14**. Since the expandable metal tubes **28** are hollow, the fluid dielectric **34** disposed within the casing **12** is free to circulate through the hollow expandable metal tubes **28**, thus aiding in cooling the transformer **10**. An insulating member **32** is disposed between the leg **20** of the magnetic core **14** and each of the expandable metal tubes **28**. The purpose of the insulating member **32** is to prevent contact between the expandable metal tubes **28** and the exposed edges of the metal laminations **30** which comprise the leg **20** of the magnetic core **14** to prevent the expandable metal tubes **28** from short circuiting the metal laminations **30**. After the expandable metal tubes **28** have been expanded, they provide a tight fitting relationship between the leg **20** of the magnetic core **14** and the winding support member **26**. The expandable metal tubes **28** are fabricated of a low carbon steel, approximately 0.030 inch thick. Once expanded, the expandable metal tubes **28** provide firm support for the winding support member **26** against the leg **20** of the magnetic core **14** throughout the axial length of the winding support member **26**. By providing the tight fitting relationship, the expandable metal tubes **28** insure that the winding support member **26** will not shift. The expandable metal tubes **28** will not collapse during the life of the transformer **10** because the pressure required to expand the expandable metal tubes **28** to the second expanded cross-section shape is greater than any mechanical stress that may be impressed upon the expandable metal tubes **28** during a short circuit condition.

Referring now to FIG. **3**, a cross-sectional view of one shape of expandable metal tube **28** utilized in the invention is illustrated. The expandable metal tube **28** is shown in its first normal cross-section shape. The appropriately shaped expandable metal tube **28** is chosen for insertion into the particular void space **58**. The expandable metal tubes **28** are available in a variety of shapes; however, the expandable metal tube **28** while in the first cross-section shape is easily inserted into the appropriate void space **58** involved. There is no need for the elevated platform and insertion methods involved in the prior art when utilizing the expandable metal tubes **28**. The workman simply chooses the appropriately shaped expandable metal tube **28** for insertion into the appropriate void space. The expandable metal tube **28** need not be driven into place as was required in the prior art. In addition, there is a lesser number of shapes from which the workman must choose than there were for the wooden dowels or glass spacers utilized in the prior art.

After the appropriate expandable metal tube **28** is chosen and inserted into the selected void space, it is expanded from the first predetermined cross-section shape to the expanded second cross-section shape. When in the expanded second cross-section shape the expandable metal tube **28** provides a tight fitting relationship between the leg **20** of the magnetic core **14** and the winding support member **26**. The expandable metal tube **28**, while in the expanded second cross-section shape, assumes the shape of the void space **58** into which it was inserted, so as to provide support for the winding support member **26** against the length **20** of the magnetic core **14** throughout the axial length of the expandable metal tube **28**.

Referring now to FIG. **4**, a block diagram describing the method of fabricating an electrical inductive apparatus, such as a transformer, embodying the teachings of this invention is illustrated. The first step in fabricating the transformer **10** is stacking and securing the plurality of metal laminations **30** to form the magnetic core **14** having a cruciform cross-section. Each leg **18**, **20** and **21** of the magnetic core **14** has the plurality of discrete stepped gradations **54** extending about the perimeter of the magnetic core **14**. (FIG. **2**) Although reference will be made to the leg **20** of the core **14**, it is to be understood that the method described herein applies to fabricating each of the legs **18**, **20** and **21** of the transformer **10**.

The second step in the method of fabricating the transformer **10** is providing the insulating member **32** to insulate the exposed edges of the metal laminations **30** from direct contact with the expandable metal tubes **28**.

The third step in the method of fabricating the transformer **10** is disposing the winding support member **26** so as to axially surround the leg **20** of the magnetic core **14**. The interior surface of the winding support member **26** contacts the leg **20** of the magnetic core **14** at the plurality of contact points **56** (FIG. **2**) about the interior surface of the winding support member **26**. The axial surfaces of the leg **20** of the magnetic core **14** and the interior surface of the winding support member **26** define the plurality of void spaces **58** which extend axially between the axial surfaces of the leg 20 of the magnetic core 14 and the winding support member 26.

The fourth step in the method of fabricating the transformer 10 is providing the low voltage or secondary winding structure 24 and the high voltage or primary winding structure 22 concentrically and axially around the winding support member 26. Since the expandable metal tubes 28 provides a tight fitting relationship between the leg 20 of the magnetic core 14 and the winding support member 26, the winding support member 26 will support the winding structures 22 and 24 and prevent the collapse of the winding structures 22 and 24 during a short circuit condition.

The fifth step in the method of fabricating the transformer 10 is inserting the expandable metal tubes 28 into the void spaces 58 defined by the axial surfaces of the leg 20 of the magnetic core 14 and the winding support member 26. The expandable metal tubes 28 extend axially between the leg 20 of the magnetic core 14 and the winding support member 26 for the entire length of the support member 26.

The sixth step in the method of fabricating the transformer 10 is expanding the expandable metal tubes 28 from the first preformed cross-section shape to the expanded second cross-section shape. After the expandable metal tubes 28 have been inserted into the void spaces 58, one end of the expandable metal tubes 28 is stoppered and a fluid medium, such as oil, is disposed within the central opening of the expandable metal tubes 28. The fluid medium is then subjected to a pressure and the expandable metal tubes 28 respond to the increased pressure therein by expanding from the first preformed cross-section shape to the expanded cross-section shape. After the expandable metal tubes 28 has been expanded, they simultaneously abut the leg 20 of the magnetic core 14 and the interior surface of the winding support tube 26 which surrounds the leg 20 of the magnetic core 14. In the expanded cross-section shape, the expandable metal tubes provide a tight fitting relationship between the leg 20 of the magnetic core 14 and the winding support member 26. The expandable metal tubes 28 brace the winding support member 26 and prevent the winding support member 26 from collapsing due to the high mechanical stress imposed on the winding support member 26 during a short circuit condition. The expandable metal tubes 28 will not collapse during a short circuit condition because the force exerted on the expandable metal tubes 28 during a short circuit condition does not exceed the force required to expand the expandable metal tubes 28 from the first preformed cross-section shape to the expanded cross-section shape. After the expandable metal tubes 28 have been expanded, the stopper is removed and the oil dielectric 34, which is disposed within the transformer casing 12, can circulate through the central opening of the expandable metal tubes 28 to assist in cooling the transformer 10.

The final step in the method of fabricating the transformer 10 is disposing the magnetic core 14 within the casing 12. The magnetic core 14 has the legs 18, 20 and 21, each of the legs 18, 20 and 21 having thereon the primary winding structure 22 and the secondary winding structure 24. The winding structures 22 and 24 are supported by the winding support member 26. The winding support member 26 is supported against the legs of the magnetic core 14 by the expandable metal tube 28 in the expanded second cross-section shape.

In summary, it is seen that the invention discloses an improved method of fabricating an electrical inductive apparatus, such as a transformer, which is cheaper, more economical, and easier to manufacture. Inserting an expandable metal tube between the magnetic core of the transformer and a winding support member, then expanding the expandable metal tube by suitable means, provides a tight fitting relationship between the winding support member and the magnetic core which supports and braces the winding support member against the high mechanical stresses encountered during a short circuit condition, thereby providing a more reliable transformer.

We claim as our invention:

1. An electric inductive apparatus comprising,
 a casing,
 a magnetic core disposed within said casing,
 a winding support member axially surrounding said magnetic core,
 windings positioned on said winding support member, and,
 an expandable metallic, peripherially closed, tubular metallic, member positioned between said magnetic core and said winding support member, said metallic, member expanding in response to an increase in fluid pressure therein to provide a tight fitting relationship between said winding support member and said magnetic core.

2. The electric inductive apparatus of claim 1, wherein said magnetic core comprises a plurality of stacked metal laminations having a plurality of axial surfaces thereon, and,
 insulating means disposed between said axial surfaces of said magnetic core and said expandable, metallic, member, said insulating means preventing electrical contact between said magnetic core and said expandable, metallic, fluid-tight member.

3. The electric inductive apparatus of claim 1, wherein said magnetic core has a thin, evenly applied coating of insulating material thereon, said coating of insulating material being disposed between said magnetic core and said expandable, metallic, member, said insulating coating preventing electrical contact between said magnetic core and said expandable, metallic, fluid-tight member.

4. The electric inductive apparatus of claim 1, wherein said expandable, metallic, fluid-tight member is responsive to an increase of fluid pressure therein by expanding from a first preformed cross-section shape to an expanded second cross-section shape, said expandable, metallic, fluid-tight member in the expanded cross-section shape providing a tight fitting relationship between said magnetic core and said winding support member.

5. The electric inductive apparatus of claim 1, wherein:
 said magnetic core comprises a plurality of metal laminations stacked so as to provide said magnetic core with a cruciform cross-section, said magnetic core thereby having a plurality of discrete, stepped graduations disposed about the perimeter of said cruciform cross-section, said magnetic core having a plurality of axial surfaces,
 said winding support member comprising a cylindrical winding tube, said winding tube axially surrounding said magnetic core, said winding tube contacting said magnetic core at a plurality of

contact points along the interior surface of said winding tube, the interior surface of said winding tube and the axial surface of said magnetic core defining a plurality of void spaces which extend axially between the axial surfaces of said magnetic core and the interior surface of said winding tube, and

said expandable, metallic, member being disposed to occupy at least one of the plurality of void spaces which extend axially between the axial surfaces of said magnetic core and the interior surface of said winding support member, insulating means disposed adjacent the axial surface of said magnetic

core, said expandable, metallic, member being responsive to an increase in fluid pressure therein by expanding from a first preformed cross-section shape to a second expanded cross-section shape, said expandable, metallic, member in the second expanded cross-section shape abutting simultaneously said insulating means adjacent said magnetic core and the interior of said winding support member, said expandable, metallic, member thereby providing a tight fitting relationship between said winding support member and said magnetic core.

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