May 27, 1969 A. Y. BROVERMAN ET AL 3,447,112

AIR COOLED TRANSFORMER

Filed Nov. 16, 1967

Sheet 1 of 2

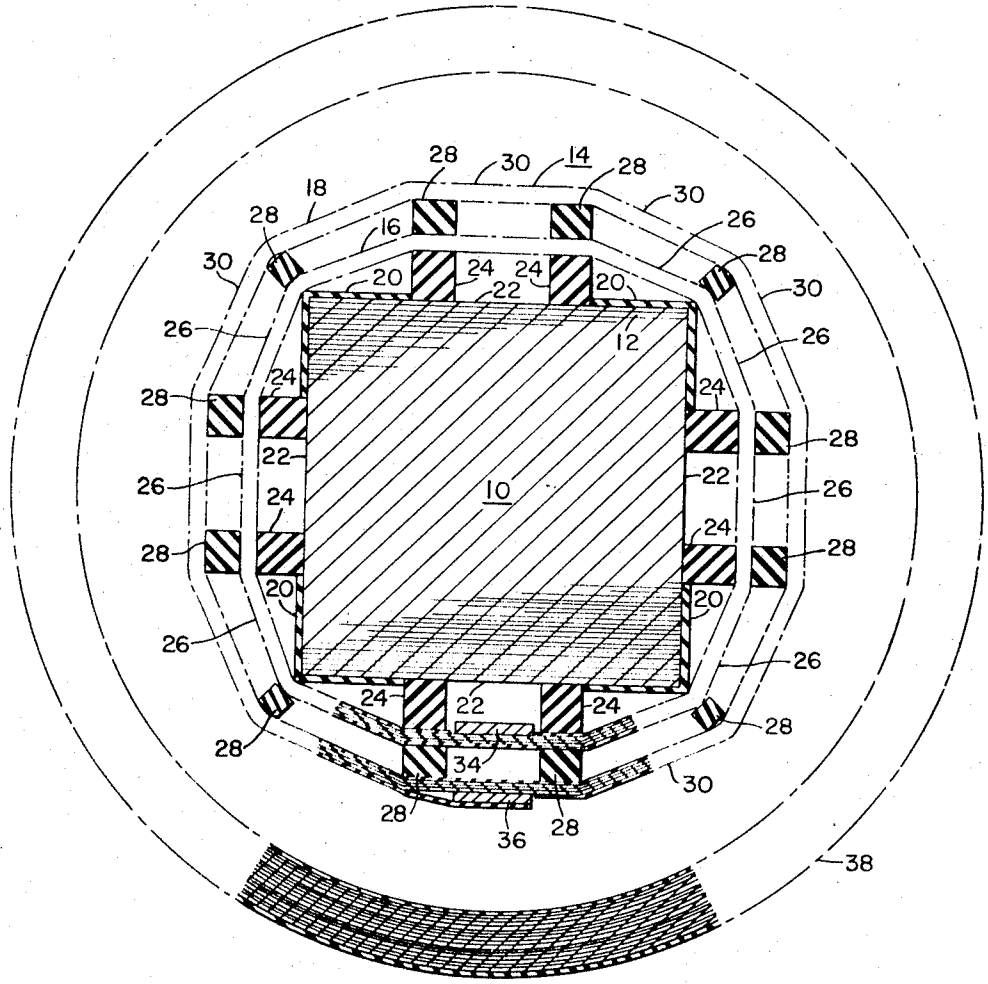


FIG. 1

WITNESSES:

Helen M. Farkas

James F. Young

INVENTORS
Alvin Y. Broverman &
Garlington C. Wilburn

BY

F. E. Browder

ATTORNEY

May 27, 1969 A. Y. BROVERMAN ET AL 3,447,112

AIR COOLED TRANSFORMER

Filed Nov. 16, 1967

Sheet 2 of 2

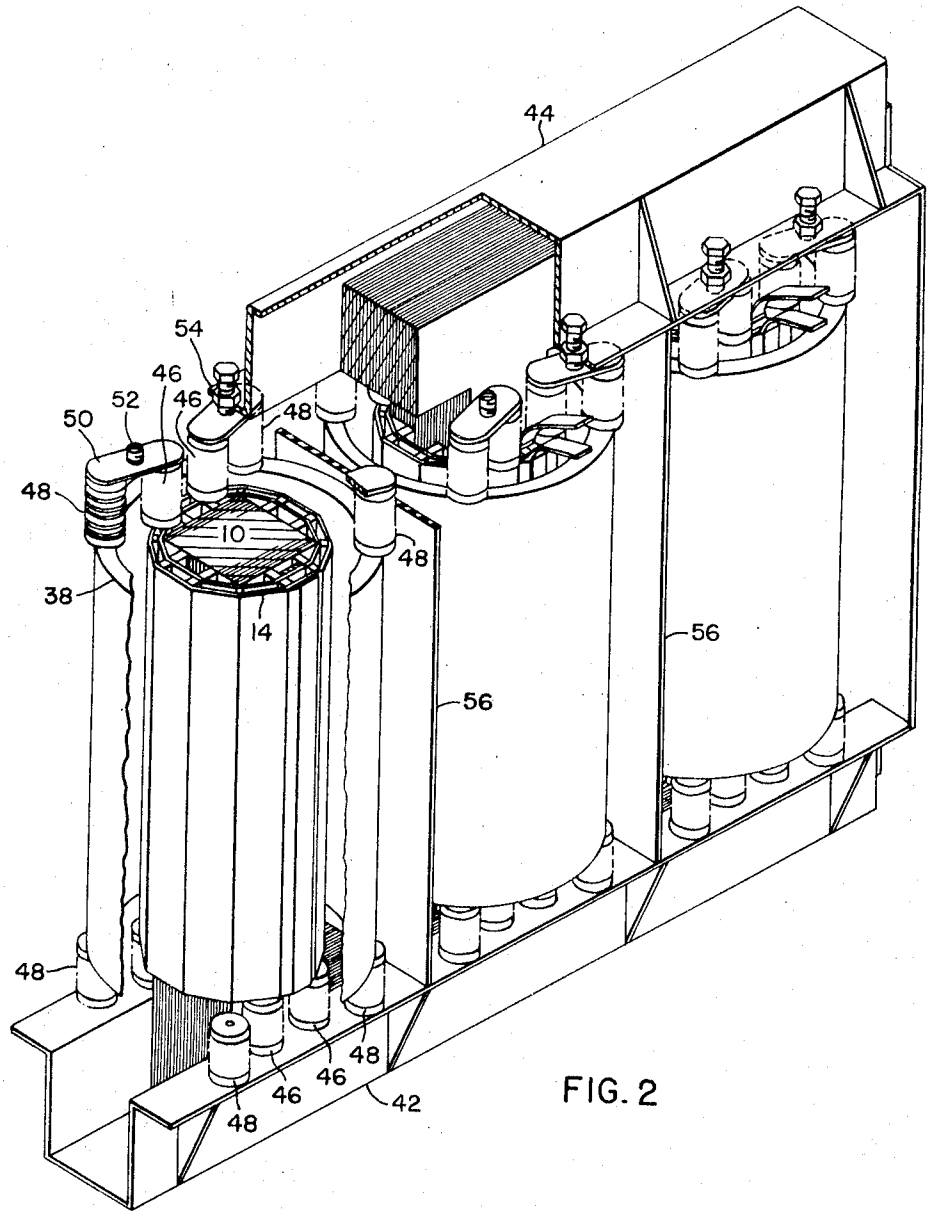


FIG. 2

United States Patent Office 3,447,112
Patented May 27, 1969

3,447,112

AIR COOLED TRANSFORMER

Alvin Y. Broverman and Garlington C. Wilburn, Sharpsville, Pa., assignors to Westinghouse Electric Corporation, Pittsburgh, Pa., a corporation of Pennsylvania

Filed Nov. 16, 1967, Ser. No. 683,532
Int. Cl. H01f 27/10, 27/30, 27/28
U.S. Cl. 336—60 7 Claims

ABSTRACT OF THE DISCLOSURE

An air cooled power transformer having concentric high and low voltage windings surrounding a square or rectangular laminated core. The outside coil is circular in cross-section and the inner concentric windings are polygonal in cross-section. Ample air space is provided between the inner winding section and the core and between the winding sections to permit circulation of air for cooling and to provide adequate insulation, using a minimum of solid insulation, to prevent overstressing the air in the air space to a potential high enough to cause corona to start. The inner winding sections are wound from sheet conductor and the outer winding may be wound from sheet conductor or conventional insulated round or rectangular strand conductor.

BACKGROUND OF THE INVENTION

Field of the invention

This invention relates to power transformers and more particularly to air cooled power transformers comprising concentric windings with at least one of the windings formed from sheet conductor.

Description of the prior art

In the prior art air cooled power transformers have been constructed by providing concentric high and low voltage windings on a magnetic core having a cruciform cross-section. This type of construction is exemplified by U.S. Patent 3,054,974. The construction provided by U.S. Patent 3,054,974 provides a satisfactory transformer but is expensive to manufacture and it is of large size. The core is made up of many different widths of thin laminations of oriented steel. This construction makes the core expensive. Furthermore, the core is insulated from the inner winding by a complete annular duct and a series of spacing blocks to provide for proper air circulation. This structure adds to the cost of the transformer and also adds to the overall size of the transformer. It is also difficult to get close coupling between the windings and the core with this type of construction.

Air cooled power transformers have also been constructed by providing a plurality of concentric circular shaped high and low voltage windings on a magnetic core having a square cross-section shape. This type of construction is exemplified by U.S. Patent 2,756,397. This structure provides a satisfactory transformer, but is subject to the same objections as the structure of U.S. Patent 3,054,974 in that too much space is required to properly insulate the inner winding from the core and this increases the overall size of the transformer, since a definite amount of air space must be provided between each of the winding sections to obtain proper cooling and to prevent overstressing the air between the winding sections and causing corona to start. With this type of structure it is also difficult to get close coupling between the inner winding sections and the core because of the solid insulation provided between the inner winding and the core.

SUMMARY OF THE INVENTION

The transformer provided by the present invention

overcomes the objections of the prior art devices by providing a two section low voltage winding wound from sheet conductor, such as copper or aluminum. A cross-section of the low voltage winding has a polygonal shape. The inner section low voltage winding is placed around a square cross-section laminated magnetic core and it is insulated from the corners of the core by sheet insulation. The inner low voltage winding is spaced from the sides of the core by spacer blocks to permit air to be circulated between the sides of the core and the inner winding and to electrically insulate the inner winding from the core. The outer section of the low voltage winding is also wound from sheet conductor and it has the same polygonal configuration as the inner section of the low voltage winding, and it is concentric with the inner section of the low voltage winding and is spaced from the inner low voltage winding by insulator spacer blocks to permit a large volume of air to be circulated axially of the coil sections, between the inner and outer low voltage coil sections. The outer low voltage winding section has the same polygonal configuration in cross-section as the inner low voltage winding section. The polygonal cross-section shape of the low voltage winding sections provides a low voltage winding which permits a close fit to the square cross-section magnetic core and also permits adequate ventilation of the winding. This close fit provides better coupling between the core and coil than can be obtained with a circular cross-section low voltage winding. This closer or better coupling between the low voltage winding and the core improves the efficiency and regulation over that of a transformer using a circular cross-section low voltage coil. The polygonal cross-section of the inner low voltage winding also occupies less space than a circular winding having the same radius as the maximum radius of the polygonal winding, that is using a radius from the center of the core to the maximum edge of the low voltage coil. This permits the use of an outer concentric high voltage winding having a smaller diameter than if the inner low voltage winding had a circular cross-section. This is true because a certain predetermined volume must be provided between the low voltage and the high voltage windings for the passage of air for cooling the windings and for insulating between the windings to prevent overstressing the air between the low voltage and the high voltage winding and causing corona to start. This structure provides a smaller overall unit because the polygonal shaped inner low voltage windings may be insulated from the core using a minimum of solid insulation and adequately blocked against the core sides for short circuit forces restraint with a minimum of solid insulation. This cuts down the possibility of overstressing the air between the low voltage winding sections and causing corona to start. The polygonal shaped inner low voltage winding occupies less volume inside a given size circular high voltage winding than an equivalent circular cross-section low voltage winding and the volume not occupied by the low voltage winding is used for insulation between the windings and for passage of cooling air. The outer or high voltage winding is circular in cross-section and may be wound from sheet conductor or it may be made up of a stack of pancake type coils wound from conventional conductor strands, with the pancake coils separated by spacer elements. The outer or high voltage winding, being circular in cross-section, need not be braced and therefore requires a minimum of solid insulation and cuts down on the possibility of corona starting in the space between the high and low voltage windings.

FIGURE 1 is a sectional end view of a transformer core and windings provided according to this invention; and

FIG. 2 is a perspective view, with parts broken away

for clarity, of a three phase transformer constructed according to this invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The same reference characters refer to the same elements through the various figures of the drawings.

FIGURE 1 of the drawing shows a cross-sectional view of a preferred embodiment of one leg of a transformer core and coil assembly as provided by this invention. In FIGURE 1 there is shown a magnetic core **10** made up of a plurality of stacked laminations **12** of oriented magnetic steel. As seen in FIGURE 1 the laminations **12** which make up the core **10** are all of the same width, and the buildup of the laminations is such as to provide a core **10** of substantially rectangular cross-section. It is desirable to use magnetic laminations of constant width to assemble the core **10** because it makes it easier and simpler to manufacture the core. This is a very economical configuration in which to fabricate a magnetic core. Cores of this type are economical because only one width of lamination is required to construct the core. However, cores of this type are difficult to fit with an economical and efficient winding construction, since if the inner winding is provided with a circular cross-section this type of winding increases the space factor and makes the overall dimension of the outer winding extremely large for a given transformer rating. This is true because this type of transformer is cooled by circulating air axially between the windings and a minimum volume of air must be circulated between the windings to prevent overstressing the air between the windings and starting corona. It is also difficult to provide this type of core with a rectangular inner winding since it is difficult to block a rectangular winding against the core for radial short circuit forces.

The invention as disclosed herein overcomes the above mentioned objections to using a rectangular core by providing the core **10** with an inner winding **14** having a polygonal cross-section. The inner winding **14** is provided in two polygonal shaped concentric sections **16** and **18** connected in series. The winding **14** is wound from sheet conductor, such as sheet copper or sheet aluminum, and each of the sections **16** and **18** comprises a plurality of layers or turns of sheet conductor insulated from each other by enamel insulation provided on the sheet conductor.

As seen in FIGURE 1, each of the corners of the magnetic core **10** is fitted with sheet insulation **20**. This insulation **20** may be any of the readily available sheet insulating materials on the market, such as the Du Pont product sold under the trade name of Nomex. The sheet insulation **20** is applied only at the corners of the core **10**, leaving side sections **22** of the core **10** bare. The first turn of the inner section **16** of the winding **14** is positioned directly against the sheet insulation **20**, and the side sections of the inner turns of the inner section **16** of the winding **14** are spaced from the sides of the core by spacer blocks **24**. These spacer blocks **24** may be made of maple wood, or any other suitable insulating material. After the first turn of the inner section **16** of the winding **14** has been placed around the core **10** and properly spaced from the sides of the core by the spacer blocks **24**, the required number of turns of conductor are then wound over the first turn. In the particular transformer shown, the first section **16** of the inner winding **14** comprises nine layers of conductor. It is seen that the inner section **16** of the winding **14** comprises three straight sections **26** between each corner of the magnetic core **10**, with a spacer block **24** placed between each of the straight sections **26**. After the inner section **16** of the winding **14** has been completed, additional spacer blocks **28** are positioned against the outer turn of the inner section **16** of the winding **14**. After the spacer blocks **28** have been properly positioned the turns of the outer section **18** of the inner winding **14** are wound over the spacer blocks **28**. In the particular transformer shown the outer section **18** of the inner winding **14** also comprises nine turns. It is seen that the outer section **18** of the inner winding **14** is also polygonal in shape and has the same configuration as the inner section **16**, with three straight sections **30** lying between each corner of the core **10**. With this construction it is seen that the inner or first section **16** of the inner winding **14** is closely coupled magnetically to the magnetic core **10** and occupies less space than a circular winding having as its cross-sectional radius the maximum dimension from the center of the core **10** to the edge of the outer section **18** of the inner winding **14**. This structure provides an inner winding which is closely magnetically coupled to the magnetic core **10**, and improves the efficiency of the transformer and also improves the regulation and permits a transformer of a given rating to be built of smaller size than a transformer having an inner winding with a rectangular cross-section or a circular cross-section.

The spacer blocks **24** must be of sufficient dimension to permit a predetermined volume of air to be circulated between the inner turn of the inner section **16** of the inner winding **14** to conduct heat away from the core **10** and the inner section **16** of the winding **14**. In view of the fact that the sections **22** of the core have no insulation thereon, heat from the core **10** will be conducted to the sections **22** where it may be readily removed by air circulating between the sides of the core and the inner turn of the inner section **16** of the inner winding **14**. The spacer blocks **29** are dimensioned so as to provide for a predetermined volume of air to be circulated between the inner section **16** and the outer section **18** of the inner winding **14**. It is emphasized that the inner winding **14** is wound of sheet conductor, and it is not possible to circulate air radially to cool the core **10** and the inner winding **14**, all of the cooling air must be circulated axially of the coil **14**, because the coil is of substantial length and the turns of sheet conductor provides a structure which acts like a flue and all cooling air must be circulated axially of the coil.

Terminal means **34** and **36** are provided for connecting the inner or low voltage winding **14** to an external circuit.

In FIGURE 1 there is shown an outer winding or high voltage winding **38** for the transformer. This outer winding **38** may also be wound of sheet conductor, such as aluminum or copper, coated with insulating enamel, or it may be made up of conventional pancake coils wound from stranded conductors and stacked with spacers therebetween so that air may be circulated radially and axially to cool the outer winding **38**. The outer winding **38** is provided of circular cross-section so that the winding will brace itself and no additional bracing will be required to hold the winding in proper shape upon a short circuit, it being commonly known that any coil tends to assume a circular shape when a short circuit is applied thereto. However, a certain predetermined volume of air must be circulated between the inner winding **14** and the outer winding **38** to properly cool the windings. It is pointed out that with the polygonal coil configuration of the inner winding **14** it is permissible to use a winding **14** having a smaller maximum radial dimension than a winding having a circular cross-section and still provide the predetermined volume between the inner winding **14** and the outer winding **38** to permit circulation of air between the windings to adequately cool the windings. Because a predetermined volume between the windings **14** and **38** can be provided by using a polygonal inner winding with the smaller maximum radial dimension than an equivalent circular winding, this permits the building of the transformer with an outer or high voltage winding **38** having a smaller dimension than is possible using a circular cross-section winding **14**. This cuts down on the overall dimension of the transformer structure. Terminal means (not shown) are also provided for connecting the outer or high voltage winding **38** to an external circuit.

The outside coil **38** should have a circular cross section in order that it may withstand the radial short-circuit forces. During a short circuit, the inside winding **14** is put into compression and the outside winding **38** is put into tension; i.e., the inside winding **14** is pushed toward the core **10** and the outside winding **38** is pushed away from the inside winding **14**. If the outside winding **38** is of circular cross-section, then the short circuit forces resolve themselves into tensile forces in the winding conductor, thus making bracing of the outside winding **38** unnecessary. If a rectangular cross-section were used in the outside winding **38**, the short circuit forces would tend to shape the rectangle into a circle. Bracing would then be required for the outside winding **38**. In dry type transformers, which are usually designed for high temperatures, the expense of high temperature bracing insulation for a rectangular outside winding **38** could not be tolerated.

To minimize waste from a poor space factor, the outside dimension of the inside winding **14** and the inside dimension of the outside winding **38** should be concentric to each other, with the inside winding progressing to the shape of a polygon.

Referring to FIG. 2, which shows a three-phase transformer constructed in accordance with the teachings of this invention, the transformer of FIG. 2 comprises a three-legged core **10** constructed of stacked laminations all having the same width as described hereinbefore. The laminations **10** are held in position by a conventional bottom frame member **42** and a top frame member **44**. Each of the three legs of the core **10** is fitted with inner and outer windings **14** and **38** as shown in detail in FIG. 1. The inner winding **14** is the low voltage winding and the outer winding **38** is the high voltage winding. The low voltage winding **14** is supported on the bottom frame member with four insulators **46** and likewise spaced from the top frame member by four insulators **46**. The high voltage winding **38** is supported from the bottom frame by four insulators **48** and likewise spaced from the top frame member **42** with four insulators **48**. A plate member **50** having a screw threaded stud **52** extending therefrom is positioned on the top insulator so that the plate **50** rests on an insulator **48** which is positioned against a high voltage winding **38**, and an insulator **46** which is positioned against a low voltage winding **14** and the stud **52** extends through a threaded hole in the flange on the top frame member **44**. The stud **52** is tightened to apply pressure to the insulators and a nut **54** is tightened against the flange on the upper frame member **42** to firmly hold the outer winding **38** and the inner winding **14** in position between the bottom frame member **42** and the top frame member **44**.

A phase separator **56** is positioned between each phase of the transformer shown in FIG. 2. This phase separator is made of some satisfactory insulating material, which is good for the design temperature.

The transformer of FIG. 2 is cooled by passing an air blast between the inner or low voltage winding **14** and the core **10** and between the inner or low voltage winding **14** and the outer or high voltage winding **38**. This air blast may be passed vertically upward or vertically downward between the elements of the transformer and the specific direction of air travel comprises no part of this invention.

A 750 kva. air cooled transformer constructed according to this invention with all of the laminations of the core **10** of the same width and with a polygonal inner or low voltage winding **14** fitted to the magnetic core **10** as described herein is more economical to manufacture than a conventional transformer having an inner winding of circular cross-section, and the transformer is more efficient than a conventional transformer having a rectangular cross-section core **10** and a circular cross-section inner winding, because the polygonal winding **14** may be more tightly coupled to the magnetic circuit **10** than a circular or rectangular inner winding. Also less insulation is required to insulate the polygonal winding **14** from the core **10**, and still provide adequate air space for circulating air between the winding **14** and the core **10** to adequately cool the winding and the core, than is possible with an inner winding of circular cross-section.

From the foregoing description taken in connection with the drawings, it is seen that the invention described herein provides an air cooled transformer utilizing a magnetic core of substantially rectangular cross-section, which is substantially more economical than a transformer using a cruciform cross-section core, since all of the laminations are the same width and may be cut with the same tool. The transformer also uses a polygonal inner or low voltage winding which may be more closely fitted and electrically coupled to the rectangular cross-section core than a circular cross-section winding. The inner or low voltage winding also may be better electrically braced against the core, since the polygonal cross-section winding is made up of a plurality of straight sections which may be braced at the ends of each straight section. Such a structure, even though it is made up of a plurality of straight sections which provides a polygonal cross-section, approaches the electrical equivalent of a circular cross-section coil, in that it has less tendency to try to approach a circular cross-section when short circuited than a rectangular coil. In other words, it may be better braced to prevent it approaching a circular cross-section when short circuited than a coil of rectangular cross-section. It is also seen that the polygonal cross-section of the inner or low voltage coil permits the building of a transformer having a smaller overall maximum leg radius than a conventional transformer using an inner coil of circular cross-section.

We claim as our invention:

1. A transformer comprising a magnetic core, said core comprising a plurality of laminations of substantially the same width stacked to provide a core having a substantially rectangular cross-section with four corners, a first winding surrounding said core, said first winding being wound from sheet conductor, said first winding being closely adjacent to and insulated from said core at the corners of said core, the insulation between said winding and said corners of said core being discontinuous between adjacent corners of said core, said first winding being spaced from said core between corners of said core to permit air to circulate against the sides of said core where said insulation is discontinuous, said first winding having a polygonal cross-section with a plurality of straight sections of each turn lying between each pair of adjacent corners of said core, and a second winding surrounding said first winding and spaced from said first winding to provide insulation between said first winding and said second winding and permit air to be circulated between said first winding and said second winding.

2. A transformer as specified in claim **1** wherein said first winding is a low voltage winding and said second winding is a high voltage winding.

3. A transformer as specified in claim **1** wherein said first winding is a two-section low voltage winding and said second winding is a high voltage winding.

4. A transformer as specified in claim **2** wherein said low voltage winding is separated from the sides of said core by means of solid insulation spacers and the sections of said low voltage winding are separated from each other by solid insulation spacers to permit air to be circulated between said low voltage winding and said core and between the sections of said low voltage winding.

5. A transformer as specified in claim **4** wherein solid insulation spacers are placed between said core and predetermined points on each straight section of said polygonal coil to permit air to be circulated between said core and said polygonal coil.

6. A transformer as specified in claim **1** wherein said first winding is insulated from the corners of said core

with sheet insulation and insulated from the sides of said core with solid insulation spacers to permit air to be circulated between the sides of said core and the inner turns of said first coil.

7. A transformer as specified in claim 1 wherein said second winding is circular in cross-section.

References Cited

UNITED STATES PATENTS

949,082	2/1910	Mattman	336—60 XR
1,317,280	9/1919	Ellis	336—197 XR
1,411,619	4/1922	Frank	336—227 XR
1,608,891	11/1926	Lee	336—60 XR
2,014,540	9/1935	Thomas	336—60 XR
3,386,060	5/1968	Reber	336—60 XR

LEWIS H. MYERS, *Primary Examiner.*

T. J. KOZMA, *Assistant Examiner.*

U.S. Cl. X.R.

336—185, 197, 227