May 26, 1959 K. C. BUGG 2,888,654

TRANSFORMERS

Filed Feb. 2, 1953 2 Sheets-Sheet 1

Fig. 1

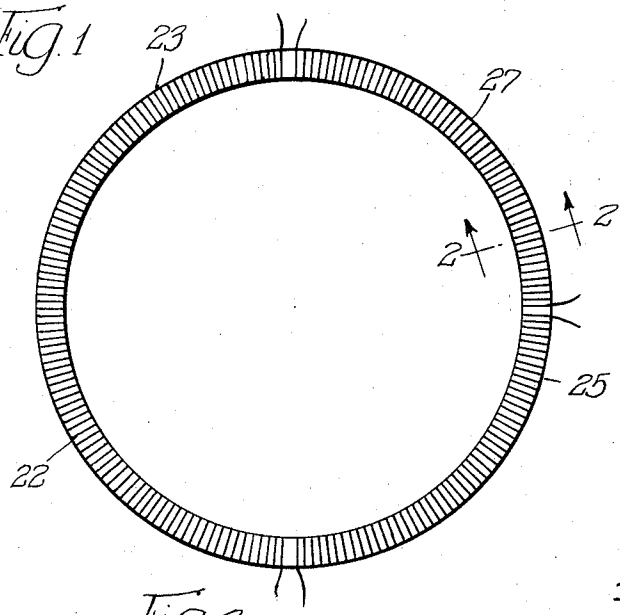


Fig. 3

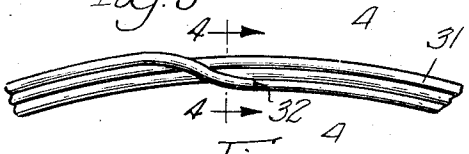


Fig. 5

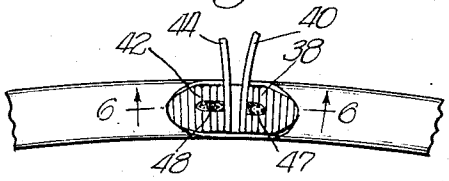


Fig. 6

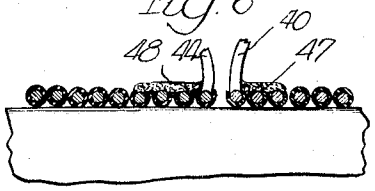


Fig. 2

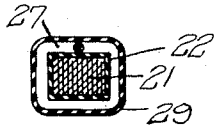


Fig. 4

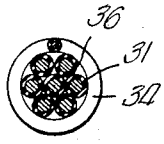


Fig. 7

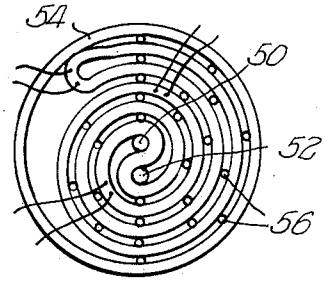
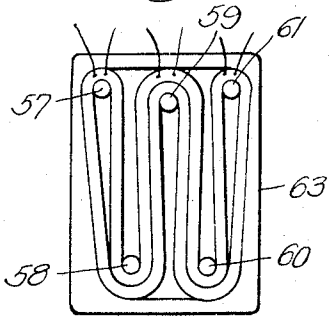


Fig. 8



INVENTOR.

Kenly C. Bugg,

BY

Wilkinson, Huxley, Byron & Hume

Attys

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TRANSFORMERS

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Fig. 9

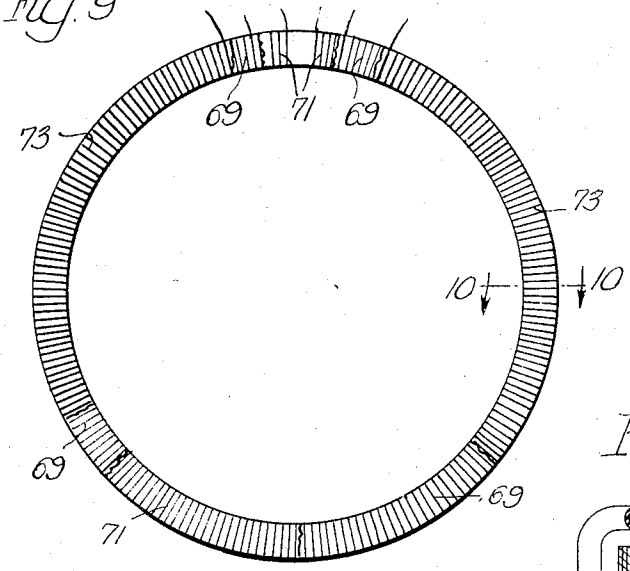


Fig. 10.

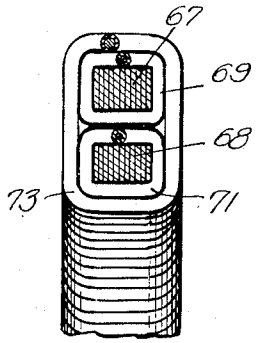


Fig. 13

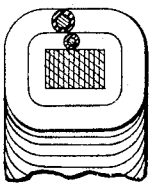


Fig. 11

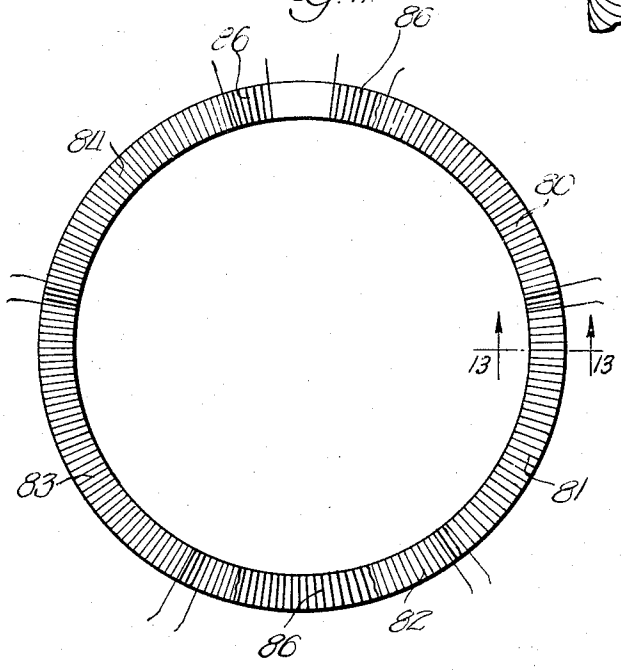
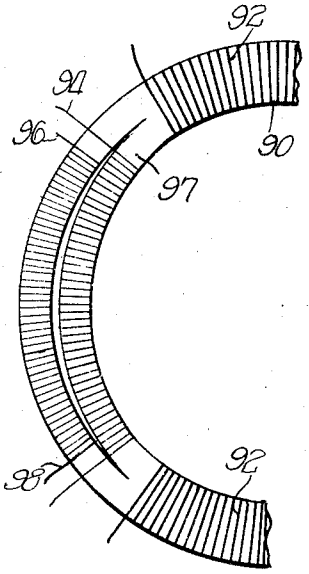


Fig. 12



INVENTOR.
Kenly C. Bugg,
BY
Wilkinson, Huxley, Byron & Hume
Attys

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2,888,654

TRANSFORMERS

Kenly C. Bugg, Fort Wayne, Ind., assignor to Kendick Manufacturing Company, Inc., Fort Wayne, Ind., a corporation of Indiana

Application February 2, 1953, Serial No. 334,450

8 Claims. (Cl. 336—221)

This invention relates to a new and improved transformer construction and more particularly to iron core transformers in compact form.

More specifically the invention relates to transformers initially wound on cores generally toroidal in design, which cores are flexible or deformable. Such transformers, after winding, are deformed to render the transformer more compact and also more rigid.

Iron core transformers have come into wide use in electronic circuits even in the higher frequency range with the development of various types of cores such as powdered iron cores having low hysteresis and eddy current losses at such frequencies. Since compact construction is an essential of many modern types of electronic construction, it is desirable to provide coil types with a minimum external field and also with a minimum pickup of energy from adjacent units in the circuit. A toroidal coil answers both of these latter requirements but as usually constructed is not compact. Another requirement, in many electronic circuits, is an exact ratio between the reactance of the primary and secondary windings of the transformer. With usual types of transformers the primary and secondaries are wound together and form a single unit when assembled on the core. It is therefore very difficult from a practical standpoint to adjust their specific inductance or their inductance ratios after the transformer is assembled. In spite of care in the winding and assembly it is impracticable to provide absolutely uniform transformers on a commercial scale. Many present day circuits require accuracy and uniformity within a tolerance of one percent or less. It has therefore been the practice to adjust the circuits externally of the transformer as, for example, by adding a series resistance which must itself be very accurate, thus increasing both the cost and the volume taken up by the equipment.

The usual type of transformer with multilayer coils is not only difficult to adjust but difficult to wind within reasonable tolerances as to circuit constants. The several layers are not uniformly wound and also each layer has a different turn radius which varies further if the turns are overlapped or scramble wound. The distributed capacity of such a coil is another variable affecting the effective reactance of the transformer coils in final assembly. While a toroidal transformer is efficient and avoids many of these difficulties it is not generally practical for the reason that such a transformer, as usually constructed, has a large size relative to other forms of transformers of equal circuit characteristics.

It is an object of the present invention to provide a new and improved compact form of transformer and method of producing the same.

It is a further object to provide a transformer wound as an open toroid and thereafter compacted to reduce the space occupied and to render the transformer more rigid.

It is an additional object to provide a transformer of this character in which the reactance of the several

windings may be maintained within close limits as they are wound and may be adjusted after winding.

It is also an object to provide a transformer having a continuous closed core which is flexible so that it may be bent to form a compact assembly.

It is another object to provide a transformer having a continuous core with windings thereon and compactly bent upon itself and held in a housing with portions of the windings exposed for adjustment.

It is a further object to provide a construction of this character with a core of sufficient length so that the desired windings may be formed thereon without the requirement for a multiplicity of winding layers.

It is an additional object to provide a transformer construction which is simple to wind, form and adjust and which is compact and rigid in final form.

Other and further objects will appear as the description proceeds.

The transformer described herein may be wound by means of the apparatus disclosed in my copending application Serial No. 296,784, filed July 2, 1952.

I have shown certain preferred embodiments of my invention in the accompanying drawings, in which—

Figure 1 is a plan view of one form of construction;

Figure 2 is a section taken on line 2—2 of Figure 1 on enlarged scale;

Figure 3 is a fragmentary plan view of a modified form of core;

Figure 4 is a section taken on line 4—4 of Figure 3 with a coil wound thereon;

Figure 5 is a fragmentary plan view showing coil ends with adjacent turns soldered together;

Figure 6 is a section taken on line 6—6 of Figure 5 on an enlarged scale;

Figure 7 is a plan view, on a reduced scale, of a transformer coiled in a casing;

Figure 8 is a view similar to Figure 7, but showing a transformer folded in a casing;

Figure 9 is a view similar to Figure 1 showing a multiple core transformer;

Figure 10 is a section, on an enlarged scale, taken on line 10—10 of Figure 9;

Figure 11 is a view similar to Figure 1 showing a two layer winding transformer;

Figure 12 is a fragmentary view showing a split core construction; and

Figure 13 is a cross section of Figure 11 taken on line 13—13.

Referring first to the construction of Figures 1 and 2, the toroidal core 21 is formed of a single length of suitable ribbon of magnetic material wound upon itself in spiral form with adjacent convolutions in close contact. This core is shown as covered with a layer of insulation 22 which may be formed of any suitable material such as plastic or varnish sprayed or brushed on or applied by dipping. It will be also understood that the insulation may comprise tape wrapped around the toroidal core or in some cases insulation of the entire core may be eliminated. In such case, the core ribbon will be insulated before it is wound and the cut ends may then be treated with an insulating coating before or after the winding. This ribbon of magnetic material may be a unitary strip of suitable iron or steel or for higher frequency use it may comprise powdered iron carried in a plastic envelope or bonded by suitable plastic. As an alternate form the ribbon may be of plastic with the powdered iron carried by adhesive on the face of the ribbon. The important feature is that the complete core be flexible or deformable. Iron ribbons may be made sufficiently thin so that they are very flexible and are adequately flexible even when wound in toroids of a number of adjacent turns so that they may be deformed as shown

herein. By way of example, the ribbon may be of the order of a thousandth of an inch thick. For some uses the core need be only on the order of a quarter of an inch or less wide and thick. When such a core is originally formed as a toroid several inches in diameter it may be readily deformed as shown. The core may also be wound of very fine wire. Numerous plastic materials are also capable of carrying iron powder while remaining flexible and readily deformable. The insulating materials used may be selected from the numerous insulating varnishes and plastics available which are readily flexed. The windings which carry the current will normally comprise fine copper wire as is usual in transformers.

The primary winding **23** is shown in this case as extending around substantially 180° of the core while the secondary windings **25** and **27** are shown as each extending approximately ¼ of the circumference of the toroidal core. These windings are single layer windings. As shown in the section of Figure 2, an insulating coating **29** is applied over the entire assembly after the windings are completed. This final coating may be eliminated in some cases and in other cases it will not be applied until later in the process of assembling the transformer in its compact form.

The core shown in Figures 3 and 4 differs from that shown in Figures 1 and 2 in that it consists of a spirally wound rod or wire **31**, the ends of which are brought together and butt welded, as shown in **32** if the wire is of solid metal. As described in connection with the core of Figures 1 and 2, this rod **31** may consist of a suitable plastic with powdered iron embedded therein. As another alternate form, it may consist of a plastic filament with a surface coating of powdered iron. As shown in Figure 4, the transformer windings **34** are wound on the core wire **31** in the same manner as the winding on the construction of Figures 1 and 2. In the form of construction shown in Figure 4, the wire **31** is shown as coated throughout with an insulating covering **36** which may take the form of a plastic or other synthetic material or of enamel or varnish applied in any usual manner.

Figures 5 and 6 show a method of adjusting the relationship between the inductance of the several coils of the transformer after the transformer has been wound. In this case the windings have been made on the long side, that is, each winding to be adjusted is provided with a few more turns than have been found to normally be necessary so that any adjustment required can be made by shorting out turns. The winding **38** is shown as terminating in a lead wire **40**, while the winding **42** is shown as terminating in a lead wire **44**. These windings and terminals might be, for example, adjacent ends of secondaries, such as secondaries **25** and **27** shown in Figure 1. The primary **23** may be wound with a predetermined number of turns and to give a specific example, it may be desired to impress 100 volts on the primary and to induce 50 volts in each of the two secondaries. The induced voltage in each secondary may then be measured and turns adjacent the leads **40** and **44** shorted until the secondaries show voltages of exactly 50. This shorting may be accomplished by scraping off some insulation from the wire of turns adjacent to the lead wires as, for example, by the use of small V-shaped files. The wires are then shorted by small solder segments **47** and **48** as shown. It will be understood that the secondaries may be brought into proper balance by removing turns of wire if desired.

The cores used in both forms of construction shown are wound with the coils while in the forms of toroids having relatively large openings, as shown in Figure 1, although they need not be maintained in circular form during the winding. Such large openings greatly facilitate the winding of toroids on usual coil winding machines. A transformer of this relative size, however, is impractical for several reasons. Present day electronic apparatus is becoming more and more condensed in size and consequently transformers as well as other components must be reduced in size. Another important difficulty with a toroidal transformer, as shown in Figure 1, is the fact that distortion or vibration or bending of any kind will temporarily or permanently destroy the accurate balance between the voltages of the several windings. A toroid of this size and proportion is extremely difficult to mount and maintain rigidly.

Figure 7 shows one form of compacting the toroid and rendering it rigid and relatively immovable. It will be understood that the cores shown in Figures 1 to 4 are flexible or readily deformable. The wound transformer of Figure 1 or the like is stretched to bring it to the form in which it comprises two long generally parallel portions joined by short arcuate portions at each end. In a suitable jig, one end of the transformer is looped around a pin **50**, as shown in Figure 7. A second pin **52** is located adjacent pin **50** and spaced therefrom by approximately the width of the cross section of the wound transformer, as shown in Figure 7. The transformer is then arcuately bent in spiral form so that it may be fitted within a cylindrical or ring-shaped housing or holding member **54**.

In the construction shown in Figure 7, a plurality of smaller pins **56** are placed at intervals so as to maintain the transformer portions spaced from each other and from the housing **54**. All of these pins may be loosely placed in a suitable jig so that after the winding has been completed and the ring **54** put in place, the transformer may be removed with the pins **50**, **52** and **56** held in place by the transformer and housing. As an alternate form, the housing **54** may take the form of a cup with a closed bottom and an open upper face and the pins **50**, **52** and **56** may be permanently secured in place in the cup. The pins **50**, **52** and **56** will usually be formed of non-magnetic and non-conducting material.

The form of construction shown in Figure 8 is similar to that shown in Figure 7 with the exception that instead of the transformer being spirally wound, it is folded upon itself around the pins **57**, **58**, **59**, **60** and **61**. It is then held in its formed position by the housing **63**. It will be understood that the number of folds and number of pins may be varied as desired. Here again the housing **63** may be a rectangular member, open at the top and bottom, or it may have a closed bottom supporting the pins **57** to **61** inclusive.

In the forms of construction shown in Figures 7 and 8, the relative inductance of the primary and secondaries may be and normally will be adjusted after the transformer has been distorted and compacted. This can be accomplished by the method shown in Figures 5 and 6. It is also possible, due to the clearances afforded between turns by the spacing and holding pins, to remove turns from or to add turns to any of the windings as may be necessary after the transformer has been installed in the housing. Should it be desired to remove or add turns, the housing is preferably in the form of a ring or frame rather than in the form of a cup.

The form of construction shown in Figures 9 and 10 includes a plurality of flexible cores **67** and **68** having the windings **69** and **71** wound upon them respectively. A third winding **73** is shown as wound around the two cores **67** and **68** and their windings **69** and **71**. Normally the windings **69** and **71** will be secondaries while winding **73** is a primary. It will be apparent that the arc, covered by the various windings, may be proportioned so that portions of both secondaries are exposed and not covered by the primary. Thus it is possible to make suitable adjustment of the inductance of the various windings after the windings have been put in place.

The form of construction shown in Figure 11 differs from that shown in Figure 1 in that the secondaries **80**, **81**, **82**, **83** and **84** are shown as superposed over the primary winding **86**. A portion of the primary winding, however, is exposed so that its inductance may be adjusted

as well as the inductance of any or all of the secondaries. The form of construction shown in Figure 12 includes a core **90** which may be formed either of wire or flat tape as shown in Figures 2 or 4. A primary winding **92** is shown as wound on the entire core for a portion on the circular arc. The core is then divided and a secondary **94** is wound on one portion of the core while another secondary **96** is wound upon the remainder of the core. The core, being flexible, it will be apparent that the core may be divided in this manner and separated sufficiently to facilitate the winding of the two secondaries. After the secondaries are wound, the two portions **97** and **98** of the core may be brought together to bring the secondaries adjacent each other and to cause the transformer to assume the general appearance of the toroids of Figures 1, 9 and 11. It will be understood that the forms of construction shown in Figures 9 to 12 may also be deformed and compacted, as shown in Figures 7 and 8.

It will be apparent that the invention may take any one of a variety of forms as to core design and construction and as to the exact arrangement by means of which it may be compacted and held rigid in its final form. All forms, however, include a continuous toroidal core or cores. It will be understood that the cross section of the toroid may be rectangular, as shown in Figure 2, or circular, as shown in Figure 4, or may take other suitable shapes. After the transformer has been compacted as shown in Figures 7 and 8 or in any other suitable manner and has been adjusted for use it may be embedded in any suitable plastic material or the like which will not adversely affect its electrical characteristics. In the preferred forms of construction, each winding comprises a single layer so that all coils may be uniformly spaced in commercial production to assure products having substantially uniform electrical characteristics. Where space and the electrical requirements will permit, the forms of constructions of Figures 1 to 4 inclusive are preferred. In these constructions all coils are of a single layer wound directly upon the core.

It will be understood that the constructions shown are illustrative only and I contemplate such modifications as come within the spirit and scope of the appended claims.

I claim:

1. A transformer comprising a continuous flexible magnetic core structure and flexible primary and secondary current carrying windings on said core, said core having folds to form adjacent core portions lying in a common plane.

2. A transformer comprising a continuous flexible magnetic core structure and flexible primary and secondary current carrying windings on said core, said core having folds to form adjacent core portions lying in a common plane and a housing fitted about the transformer to retain it rigidly in folded position.

3. A transformer comprising a flexible toroidal magnetic core and flexible primary and secondary current carrying windings on said core, the toroid having substantially parallel portions connected by arcuate portions, said core having folds to form a compact assembly.

4. A transformer comprising a flexible toroidal magnetic core and flexible primary and secondary current carrying windings on said core, the toroid having substantially parallel portions connected by arcuate portions, said core having folds to form a compact assembly, a housing to receive and hold said assembly and nonmagnetic spacers located between adjacent portions of the core.

5. A transformer comprising a flexible toroidal magnetic core and flexible primary and secondary current carrying windings on said core, the toroid having substantially parallel portions connected by arcuate portions, said core having folds to form a compact assembly and a housing to receive and hold said assembly, the housing exposing end portions of each of said windings whereby the length of said windings may be adjusted after assembly.

6. A transformer comprising a flexible toroidal magnetic core and flexible primary and secondary current carrying windings on said core, the toroid having substantially parallel portions connected by arcuate portions, said core having folds to form a compact assembly, a housing to receive and hold said assembly and nonmagnetic spacers located between adjacent portions of the core, the housing and spacers being formed to expose end portions of each of said windings whereby the length of said windings may be adjusted after assembly.

7. A transformer comprising a flexible toroidal core, a single layer wound primary on said core, at least one secondary wound in single layer over the primary and exposing a portion of at least one end of the primary winding, the core with the windings thereon having folds to form adjacent core portions lying in a common plane.

8 A transformer comprising a flexible divisible toroidal core, a portion of the core being divided into at least two portions, coils wound on said divided portions, at least one coil wound on the undivided portion, the core with the windings thereon having folds to form adjacent core portions lying in a common plane.

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