

Dec. 11, 1951

H. A. STRICKLAND, JR

2,577,825

TRANSFORMER

Filed Feb. 4, 1946

4 Sheets-Sheet 1

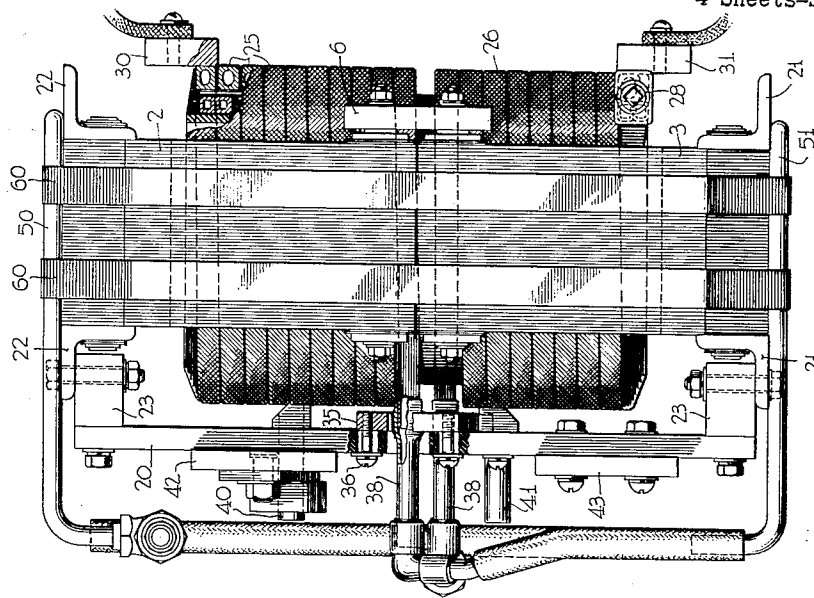


FIG. 2

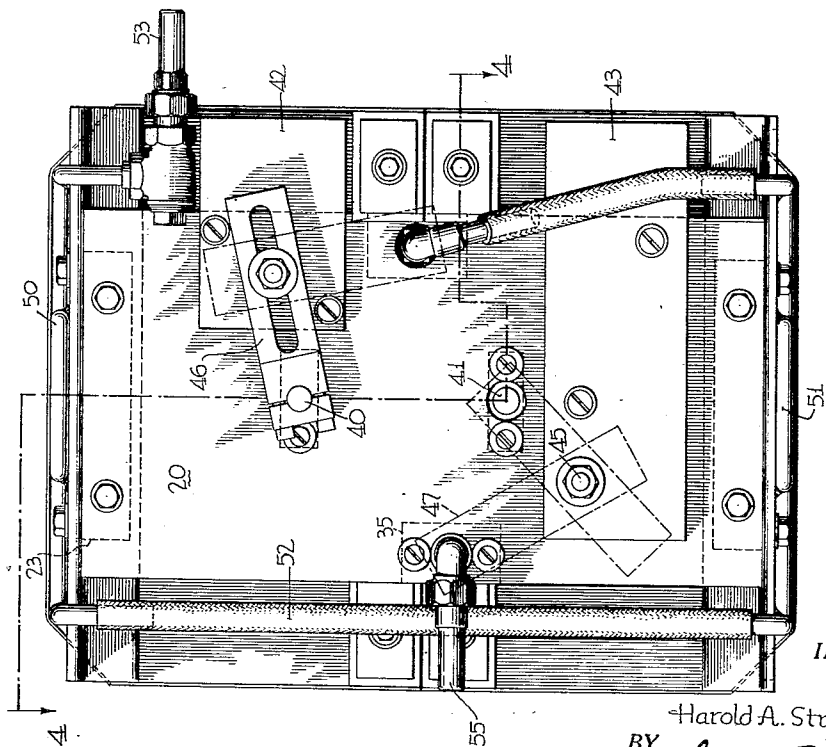


FIG. 1

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FIG. 3

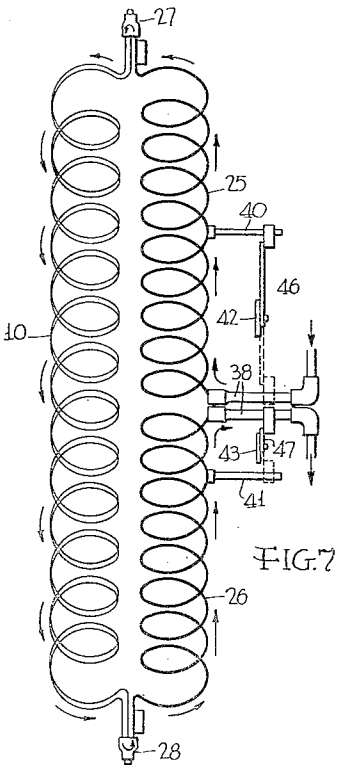
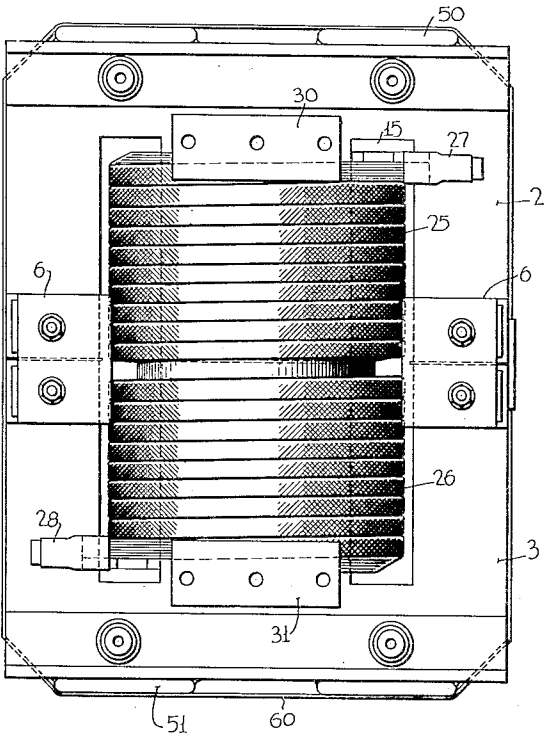


FIG. 7

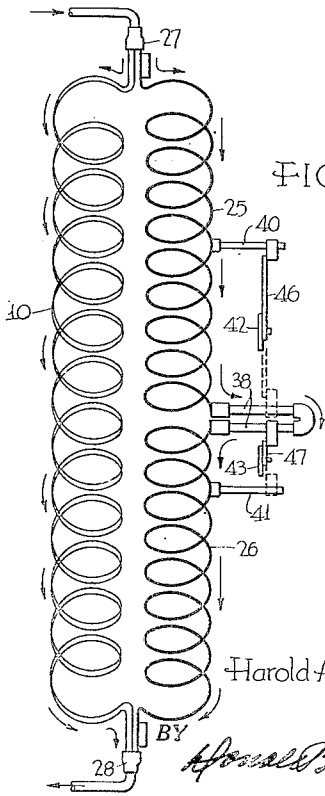


FIG. 8

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FIG. 4

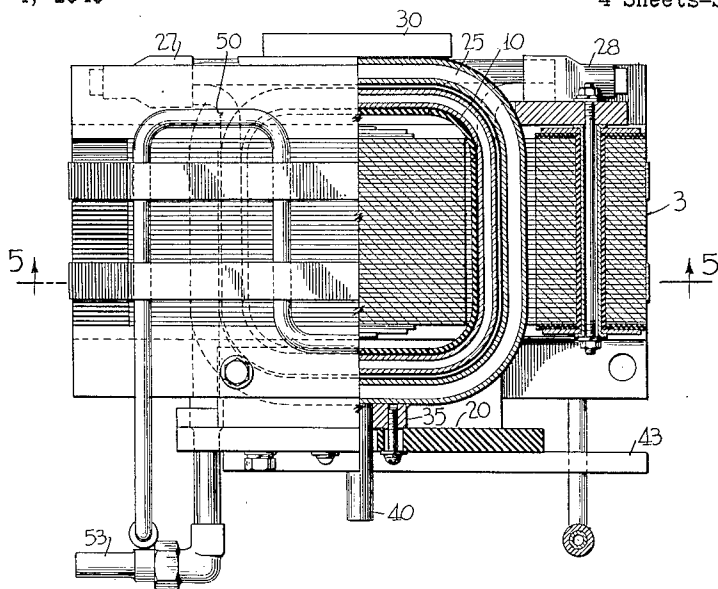
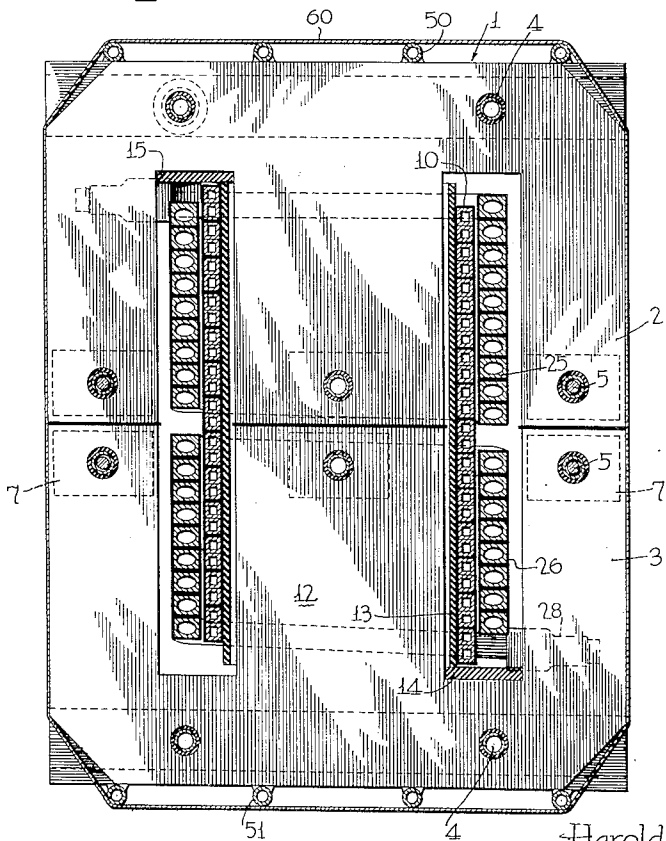


FIG. 5



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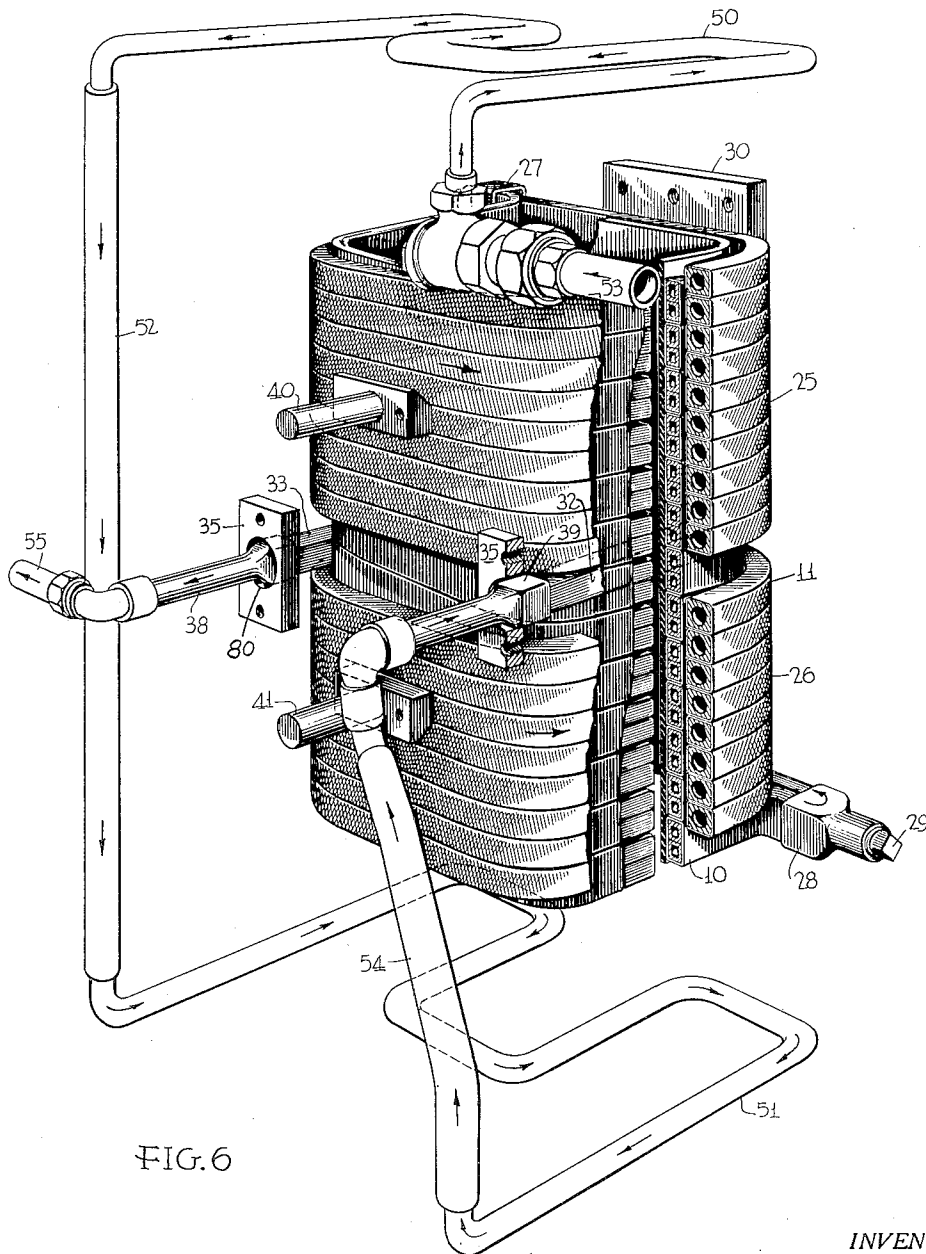
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UNITED STATES PATENT OFFICE

2,577,825

TRANSFORMER

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Application February 4, 1946, Serial No. 645,450

4 Claims. (Cl. 175—362)

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This invention relates to inductive apparatus as exemplified in transformers, with particular application to auto-transformers.

An object is to provide an auxiliary support element for the windings of a transformer including means for fixing the ends of the primary coil turns irrespective of the degree of rotation of the terminal coil section at emergence of the coil ends from the winding.

An object also is the provision of an assemblage in which connection to multiple taps may readily be made to vary the electrical condition of the windings as regards series and parallel relationships.

An object also is to facilitate the assembly of the transformer as well as improve its electrical characteristics.

Objects of the invention also pertain to improved means for cooling the transformer including structure permitting series connection of coolant to core and coil, and an arrangement whereby the core is directly cooled by conduction to reduce the over-all kilowatt consumption of the unit.

The above and other objects of the invention are achieved by the structure hereinbelow described and illustrated in the accompanying drawings, in which:

Figure 1 is an elevation of the front face of the transformer with the casing removed, showing the auxiliary support panel and bus bar connections;

Figure 2 is an elevation of the structure of Figure 1 turned 90° to show primarily the relationship of the core, coil, panel support, and core cooling unit;

Figure 3 is an elevation showing the rear side of the transformer;

Figure 4 is a plan section taken along lines 4—4 of Figure 1 illustrating the relationship of the core cooling coil and the transformer coils to the core;

Figure 5 is an elevation taken along lines 5—5 of Figure 4 showing the structure of the core segments and the relationship of the windings to the core;

Figure 6 is a perspective illustrating the cooling system and electrical windings of the transformer;

Figure 7 is a diagrammatic showing of the electrical connections of primary and secondary windings with the cooling system arranged for series movement of the coolant through the two windings; and

Figure 8 is a diagrammatic showing of the

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windings with the cooling system arranged for parallel movement of the coolant through the windings.

Referring to Figures 2, 3 and 5, it will be observed that the transformer illustrated is of the shell type in which the coils are completely enclosed by the core. The core 1 is laminated and formed of E-shaped sections 2 and 3 which are assembled in stacks and bound together by means of tubular rivets 4, as shown in Figures 1 and 5. Bolts 5 extending through certain of the rivets 4 hold in place plates 6 on the rear side of the transformer and 7 on the front side to hold mechanically the two core units 2 and 3 together. Each of the rivets 4 is preferably spaced from the laminations in the bore thereof by insulation tubing.

The transformer windings, as illustrated in the drawing, are adaptable for auto-transformer use and include a secondary coil 10 and a primary winding 11 which is wound concentrically about the inner branch 12 of the core unit as assembled. As shown more clearly in Figure 5, the lowermost turn of the secondary and an insulation tubing 13 rest on a strip of insulation 14 at the base of the annular opening formed in the core. Similarly, engaging the uppermost turn of the secondary is a second insulation strip 15. These strips 14 and 15 are so dimensioned that when the coil unit is installed in the cylindrical recess of the core, the unit is maintained snugly in place. In the method of assembly the lower core unit 3 first receives the coil unit which is previously separately wound, and then the second section 2 of the core is placed in cooperative engagement upon the first section and these units are strapped together by steel tapes 60 and bolted together by means of the plates 6, as previously mentioned.

There is provided auxiliary supporting means for the coil in a panel 20 of insulation plate or board having a width approaching the width of the transformer and of approximately the same height. This board is supported by brackets secured to the core by rivets 4, the lower brackets 21 of L shape serving also to support the core on any desired base. The upper brackets 22 are also L-shaped and held in position by the rivets 4 and extend laterally from the top of the core. Blocks 23 are bolted to these brackets and to the plate 20 so as to hold the same in position and extend the plate from the outer surface of the coil unit sufficiently to make attachment for the coil terminal plates.

As appears more clearly from Figure 6, the coil windings include an inner secondary coil 10

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and two sections 25 and 26 of primary coil concentrically related, the turns of which are rectangular in cross-section and the sectional area of the secondary turns being less than that of the primary turns. The secondary turns are shown as double, two of the smaller conductors forming a parallel conducting circuit, this being diagrammatically indicated in Figures 7 and 8. The showing of Figure 6 also brings out that the secondary turns with the insulation removed are in pairs. The purpose of this construction is to facilitate winding, to insure that the proper inductive relationship between the turns be established, and to permit proper winding of the coil so as to utilize most efficiently the space available.

At the top and base ends of the coil unit, as indicated by the numerals 27 and 28 respectively, means are provided in couplings which serve to provide either series connection between the coil turns of the primary and secondary or parallel connection, as regards the coolant connection. This is accomplished by employing the plugs 29 to close the coupling and form a continuous path therethrough for the series connection and to permit, on removal, a parallel connection to a coolant source. The primary coil turns are provided with outlet terminal plates 30 and 31, as shown in Figures 2 and 3, which are welded or otherwise attached to the limiting turns on the upper and lower ends of the primary coils. There is also provided terminal electrical and coolant connections to the primary coil ends emanating tangentially approximately at the center of the winding, the upper of these ends being indicated by the numeral 32 and the lower by the numeral 33.

In order to make appropriate physical connection of the primary ends to the supporting panel 20, I have employed a coupling which is universal in its attachability as regards rotation of the coil terminals. This is desirable since inasmuch as the cross-section of the conductor as shown is square and may be polygonal, should there be a slight rotation of the terminal due to the process of winding, it will fail to register with a receiving square opening in a holding block. To overcome this difficulty I have provided a block 35, as shown particularly in Figures 2 and 6, which is secured by bolts 36 to the panel 20 on the inner side thereof and which has a cylindrical opening 38 therein. Consequently, it appears that the coil ends 32 and 33, either as such or when extended by a coupling member 38 having an overlying fitting base 39, when lying within the cylindrical opening of the plates 35 will contact at the four corners thereof so that at these corners, irrespective of the angularity or degree of rotation of the terminal, there will be adequate contact permitting welding or other mode of attachment. The couplings 38 extending from the square fitting 39 are cylindrical in form and extend through openings in the panel 20 and beyond the same to permit engagement thereof by bus bar straps. For the same purpose taps 40 and 41 are illustrated emanating from a mid-section of the primary and extending through the panel 20 so as to afford alternate electrical connection at these points to modify the electrical characteristics of the transformer output.

Associated with the panel are two bus bars 42 and 43 by means of which primary current is supplied to the coil, the bus bar 42 supplying the upper primary section 25 of the primary and the bus bar 43 supplying the lower section 26 of the

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primary. Each bus bar is also provided with pivot bolts as 44 and 45 to which bus-bar straps in the form of slotted pivot plates 46 and 47 make connection. The tap connecting terminals of these plates are recessed and adapted to receive a similarly recessed cap block which is separable from the plate but may be attached thereto to engage either the taps 40 and 41 of the primary or the terminal couplings 38. In Figures 1 and 2 the details of this coupling means are shown only in the upper connection to the bus bar 42, the coupling member being omitted in the connection to the bus bar 43 to permit inspection of the structure without this unit.

In the description so far attention has been directed primarily to the structural features of the transformer as related to the core, the windings, and the bus bar and electrical connections to the coil. A significant part of the structure, however, pertains to the cooling not only of the coil, but of the core since by this means it is possible to markedly increase the electrical efficiency of the unit and thereby permit decrease in the size and weight. In order to insure this efficiency, both primary and secondary coils are tubular so as to permit passage of a coolant during the operation of the transformer. As previously described, the secondary winding is formed with parallel coils the conductors of each of which are tubular to receive the coolant, and hence the cooling effect is pronounced for the effective carrying capacity of the conductor. As previously mentioned, the upper terminal end of the secondary coil is joined to that of the primary coil at the coupling 27 which may be employed merely as a series enclosure, as indicated in Figure 7, or which may be connected to a coolant source which may transmit coolant in parallel between the secondary and primary coils, as indicated in Figure 8. The coupling 28 at the base junction of the secondary and primary sections also may be connected in series or parallel, as shown in Figures 7 and 8. When the connection is in parallel as in Figure 8, the coupling 38 includes an insulating conduit and is joined to terminals 32 and 33 at the inner ends of the primary sections, as indicated in Figure 8.

In addition to the cooling of the windings of the transformer as above indicated, I have found that a substantial increase in efficiency results from direct cooling of the core 1. This is accomplished by welding or otherwise attaching to the outer edges of the laminated core a segment of metallic tubing adapted to receive a coolant whereby through direct heat conduction the transformer core temperature is substantially reduced during transformer operation. To secure the greatest cooling effect the tubing is preferably sigmoid or curvilinear so as to obtain a substantially large linear area of contact. Such a cooling unit is placed on and attached to the core, as indicated in the drawings by the numerals 50 and 51, these units being connected together by an insulating tubing such as rubber tubing 52. I have found it convenient and desirable to connect the core cooling unit with the windings of the transformer so that the same coolant source may be used, as indicated by the numeral 53. For series cooling as illustrated in Figure 7, coolant entering at inlet 53 passes through the core coil 50, insulating tubing 52, core coil 51, and insulating tubing 54 to the inner terminal coupling 38 of the end 32 of section 25 of the primary coil and from this point passes through the primary coil, the coupling

27, the secondary 10, the coupling 28, and the primary section 26, passing out of the unit through the primary end 33 and terminal coupling 38 to the outlet 55. Thus it is apparent that the coolant circuit from the inlet 53 to the outlet 55 is in series, which under certain conditions is found to be advantageous in the operation of the auto-transformer. Arc welding is used to bind the cooling coils 50 and 51 to the transformer core, and the entire assembly is preferably surrounded by straps 60.

Where parallel cooling of the coils is used, the cooling circuit may be traced from an inlet at the end of tube 51 through conduit 52 and tube 50 to coupling 27. The connection from this coupling is in parallel through the primary and secondary coils to outlet coupling 28. Couplings 38 are connected by rubber tubing to establish continuity between sections 25 and 26 of the primary coil. As hereinabove indicated, one of the outstanding features of the transformer is the fact that the coil and the auxiliary supporting elements are all supported from the core. The panel 20 functions as an auxiliary support for the ends of the primary windings and this auxiliary support, in conjunction with the contact of the core plates 6 which bear against the mid-section of the primary coil, tends to restrain working of the turns due to current surges and mechanical stresses and thus to maintain the unit immobile. The cooling of the core by the sigmoid turns in direct contact therewith has a direct bearing on the efficiency by permitting absorption of greater kilowatt loss in the core than would be otherwise possible. Through this greater core absorption of energy it becomes possible to reduce the number of turns of the windings thereby increasing the efficiency and permitting a substantial reduction in the weight and cost of the apparatus. In tests made on this construction it has been found that without the cooling coils the iron loss amounted to 1.1 kilowatt, requiring a copper loss of 12 kilowatts and a total loss of 13.1 kilowatts, whereas with the cooling the iron could take a loss of 4 kilowatts, permitting a reduction of turns of the windings to a point where 6 kilowatt loss occurred in the copper in the conductors and a total loss of only 10 kilowatts. This amounts to a reduction of over 20% in the total loss of the transformer and hence permits important improvement in the design and structure and cost of the unit. Mention is again made of the advantageous mode of connection between the coil terminals and the bus bar panel to permit of engagement irrespective of the angle of rotation of the terminal. The structure of the laminations of the core in E shape facilitates the assembly of the transformer unit.

The showing made is preferred, but it is evident that modifications of details and relationships may be made coming within the scope of the claims as hereto appended.

What is claimed is:

1. A coupling comprising a generally rigid plate section having a cylindrical aperture therein, said aperture having a continuous circular surface, a joining section including a generally rigid member polygonal in cross-section positioned in said plate section aperture, the corners of said member being attached to the inner surface of the plate aperture.

2. In electrical apparatus, a generally rigid plate section having a cylindrical aperture therein, said aperture having a continuous circular surface, a joining section including an electrical conducting generally rigid member polygonal in cross section and extending at least into said plate section aperture, the corners of said member being attached to the inner surface of the plate aperture.

3. In an electrical transformer, electrical windings having polygonal-shaped ends to which electrical connection must be made, supporting means for said ends including a fixedly-supported member adjacent said windings, said member having a cylindrical opening therein, a tubular coupler at least in part polygonal in cross section attached in extension of one of said ends and positioned so as to extend through said opening with the polygonal part within said opening, and means for rigidly securing the corners of said part to the interior surface defining said opening.

4. In an electrical transformer, a conductor polygonal in cross section forming an electrical winding having polygonal-shaped ends to which electrical connections must be made, a support adjacent said winding, a busbar unit mounted on said support adjacent said winding, and means for connecting an end of the conductor with said unit, said connecting means including a coupling mounted on said support and universal as to the axial rotational angularity of said end in relation to a point in the plane of said unit, said coupling having a portion surrounding and engaging said end, said connecting means also including an electrical conductor extending from said unit to said coupling.

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