Sept. 10, 1946. A. R. WOOLFOLK 2,407,391

METHOD OF MAKING THREE PHASE TRANSFORMERS

Original Filed Nov. 29, 1943 2 Sheets-Sheet 1

Fig. 1

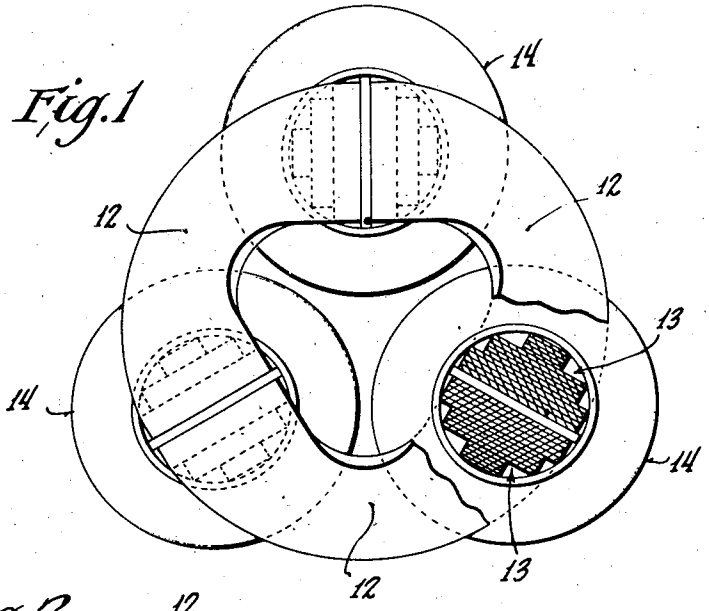


Fig. 2

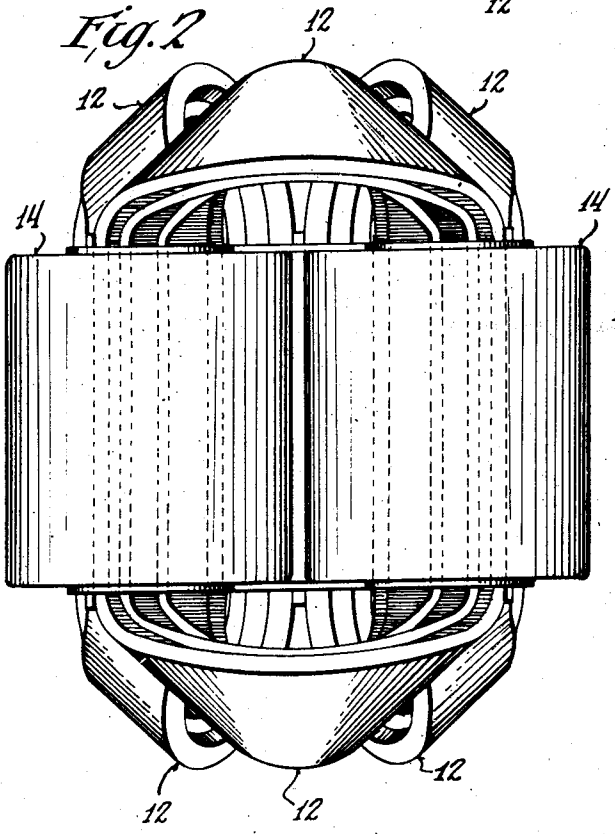
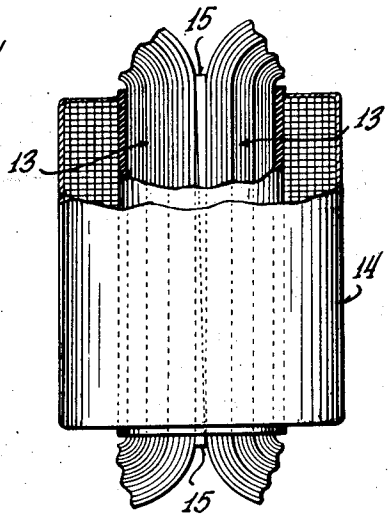


Fig. 3



INVENTOR.

Arthur R. Woolfolk

Sept. 10, 1946. A. R. WOOLFOLK 2,407,391

METHOD OF MAKING THREE PHASE TRANSFORMERS

Original Filed Nov. 29, 1943 2 Sheets-Sheet 2

Fig. 4

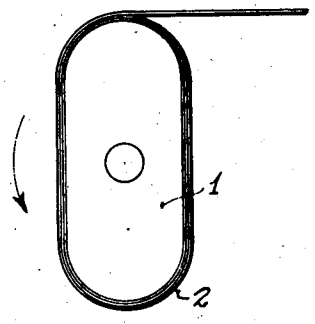


Fig. 5

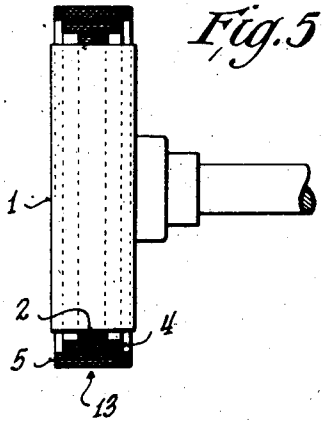


Fig. 6

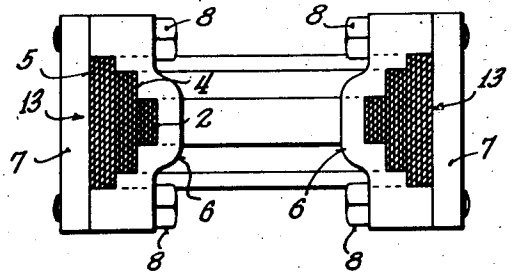


Fig. 7

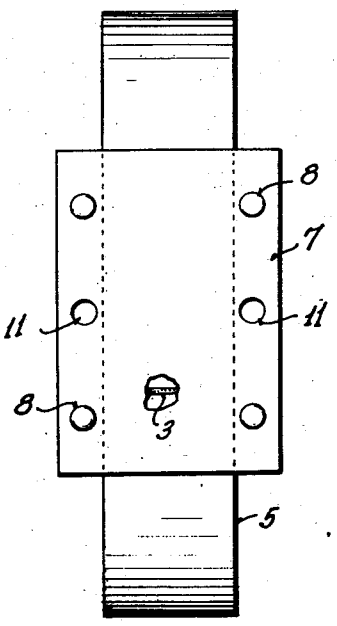
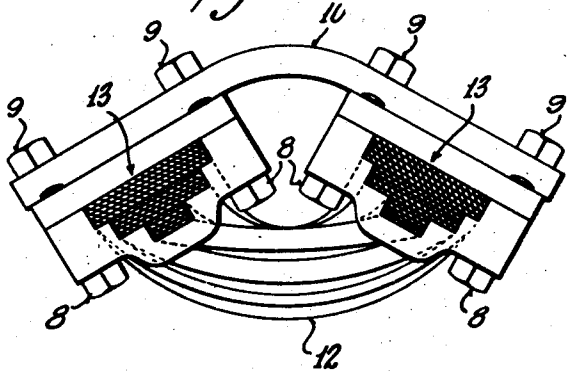


Fig. 8



INVENTOR.

Arthur R. Woolfolk

Patented Sept. 10, 1946 2,407,391

UNITED STATES PATENT OFFICE

2,407,391

METHOD OF MAKING THREE-PHASE TRANSFORMERS

Arthur R. Woolfolk, Wauwatosa, Wis., assignor to Line Material Company, South Milwaukee, Wis., a corporation of Delaware

Original application November 29, 1943, Serial No. 512,134. Divided and this application May 3, 1945, Serial No. 591,705

3 Claims. (Cl. 29—155.57)

1

This application relates to the method of making a three phase transformer.

This application is a division of my prior application for Electromagnetic device and method of making the same, Serial No. 512,134, filed November 29, 1943.

Three phase transformers have heretofore been made of the stacked core construction in which a multitude of pieces of flat core steel were joined together by stacking to form the necessary shape of core for the three groups of conducting winding assemblies of the three phase transformer. This stacking operation entailed a high labor cost due to the long process of interleaving all of the small pieces of steel. Even in the initial stacking operation some mechanical stress was always imparted to the core pieces in the practical manufacture of the transformer and this reduced the efficiency of the transformer. Also in the stacked core construction it is necessary for the magnetic flux to traverse a multitude of air gaps and to travel cross grain at the corners of the core and this entailed a certain amount of loss in the core of the transformer.

Objects of this invention are to provide a novel method of making a three phase transformer which method contemplates the winding of three closed cores from magnetic ribbon either on a rectangular mandrel or an a circular mandrel in which latter case the cores would be subsequently given a rectangular shape, in either case providing three cores each having two straight leg portions preferably of half cruciform cross-section; the clamping of the straight leg portions and rotation of such portions while they are clamped to cause the laminations in one straight leg portion to be at an angle to the laminations in the other straight leg portion with the connecting end portions outwardly arched in a smooth, gradually varying curve; the subsequent annealing of the cores while they are held clamped in shape and while the straight leg portions are held in their angular relation to each other; and the final winding of three circular conducting winding assemblies each surrounding a straight leg portion of two cores and being wound in place.

An embodiment of the invention is shown in the accompanying drawings, in which:

Figure 1 is a plan view of the transformer with parts broken away and parts in section.

Figure 2 is a side elevation of the transformer.

Figure 3 is a fragmentary view, partly in section and partly broken away, showing the straight leg portions of two of the cores and one of the conducting winding assemblies.

2

Figure 4 is a view showing one of the steps in the process of making the transformer.

Figure 5 is a view, partly in section, showing how the successive sections of one of the cores are wound on the mandrel.

Figure 6 is a view, partly in section, showing the manner of first clamping the straight leg portions of one of the cores of the three phase transformer.

Figure 7 is a side elevation of the structure shown in Figure 6.

Figure 8 is a view showing the final manner in which the straight leg portions of the core sections are held clamped and with the planes of the laminations of the core sections arranged at an angle to each other prior to annealing.

The method used in making this transformer is to first wind one section of a core of the narrowest magnetic ribbon on a mandrel 1. This section is indicated by the reference character 2. When a sufficient number of layers have been wound, the end is tack welded or brazed. Thereafter the next section of the core is wound of wider magnetic ribbon on the first section. This section is indicated by the reference character 4 and its end is similarly tack welded. Thereafter the outermost section of wider magnetic ribbon indicated at 5 is wound on top of the two previously completed sections and the end of this section is tack welded. One of these tack welds is indicated at 3 in Figure 7. Although three sections have been shown, it is to be understood that any number of sections may be employed. These sections may all be wound on a rectangular mandrel having curved end portions as shown in Figure 4, or may be wound on a circular mandrel and the straight leg portions may be shaped after winding to the rectangular shape as shown in Figure 4. Thereafter the straight leg portions are clamped in any suitable manner as by means of the clamps formed of the portions 6 and 7, which portions are bolted together as indicated at 8. It is to be noted that the innermost portions 6 are shaped to correspond to the half cruciform cross-sectional shape of the wound core.

After the clamping members 6 and 7 have been securely bolted together, they are turned at an angle to each other to the position shown in Figure 8 so that the laminations of the straight leg portions are at an angle to each other and the clamping members are then secured as by means of the bolts 9 to a rigid bracing member 10 so as to hold the straight leg portions in their angular relation to each other. This is readily accom-

plished as the clamping members may be provided with holes 11 and the bracing member with similar holes to receive the bolts 9.

It is to be noted from a comparison of Figures 6 and 8 that in reality the straight leg portions of a core are rotated and during this rotational movement the arched end portions rock outwardly at opposite ends to form a smooth, gradual arched portion indicated generally by the reference character 12. For the sake of convenience in description, the finished straight leg portions will be indicated generally by the reference character 13.

The magnetic ribbon may consist of any suitable material such as either hot or cold rolled silicon steel. The method described hereinabove is such that no sharp angles or sharp bends are imparted to any portion of the cores and instead the rounded, arched end portions connecting the straight leg portions of a core are gradually curved. This is shown clearly in Figure 2 and it will be seen that there is no abrupt change in curvature from one portion of the arched end portions 12 to any other portion of the arched end portions but that the change in curvature is gradual. In reality the arched end portions 12 are somewhat conical and have their greatest curvature on their inner edges and their least curvature on their outer edges. This is a bending operation which is readily performed and does not require any special care. The arched end portions naturally form themselves as described when the straight leg portions are turned to the position shown in Figure 8.

While the core sections are held in their bent and clamped condition as shown in Figure 8, they are annealed and after annealing the clamping means is removed and the core section will retain its shape.

After annealing there is no working of any sort—no bending, machining or any other type of working done on these core sections—and consequently there is no mechanical stress which would interfere with the magnetic characteristics of the core sections.

It is to be noted from reference to Figure 8 that the straight leg portions are arranged with the laminations in such straight leg portions at an angle of 120° to each other for each core section.

In assembling the transformer the core sections are positioned back to back as shown in Figures 1 and 2, and it is to be noted that when so positioned the straight leg portions of adjacent core sections form cruciform straight leg portions for the conducting winding assemblies indicated at 14. These conducting winding assembles include both the primaries and the secondaries and may be wound in any suitable manner directly on the cores. They may be wound, for example, on the winding machine disclosed in the patent to Steinmayer et al. No. 2,305,999 of December 22, 1942, for Method and machine for winding coils, or may be wound on the machine disclosed in the patent to Schultz et al. No. 2,334,131 of November 9, 1943, for Machine for winding coils and method of winding coils. These winding assemblies are circular and consequently have all of the inherent advantages resulting therefrom, such as the ability of the conducting winding assembly to resist distorting forces due to short-circuit or similar conditions, as a circular coil is considerably stronger than rectangular coils. In addition to this there is less danger of damaging the insulation during winding than where a rectangular conducting winding assembly is employed as the circular winding requires less tension on the wire and no pounding on the coil to make a firm coil.

After the conducting winding assemblies 14 have been completed, the core sections may be secured in place in any suitable manner. For example, elongated, flat, tapered wedges 15 of insulating material may be driven in from opposite sides as shown in Figure 3 and will lock the core sections in place.

It is to be noted from reference to Figure 1 that the axes of the three conducting windings are parallel and arranged at the apexes of an equilateral triangle. It is also to be noted particularly as set forth hereinabove that there is no sharp bending produced at the connecting arched end portions of the core sections but that the arched end portions are gradually arched and their radius of curvature varies gradually from point to point. This is an important factor in the making of a transformer as it enables the correct bending or angular positioning of the straight leg portions without unduly stressing the material at the curved and smoothly arched end portions.

It is to be noted also that due to the symmetrical arrangement of the transformer as shown most clearly in Figure 1, it is possible to mount the transformer in a circular tank.

It will be seen that the method of making the transformer may be very rapidly followed and requires a very small number of operations to produce the final transformer.

Each winding assembly surrounds or interlinks two adjacent cores and the magnetic flux does not at any time have to pass from one core to another core.

The magnetic ribbon has a grain due to rolling which extends lengthwise of the ribbon and is most permeable to magnetic flux along the grain, that is to say, lengthwise of the ribbon. This invention utilizes this most permeable path as the magnetic flux is lengthwise of the ribbons in all of the core sections.

Also it is to be noted that a very small exciting current is required as the magnetic ribbon forming the core sections is continuous and is not broken by cross cuts with the resulting air gaps but instead is, as stated, formed of continuous closed wound magnetic ribbon.

While the invention is primarily directed to a three phase transformer, it is to be understood that the core construction, and the method of making the same, may be used for other electromagnetic devices. It is to be noted further that while three main cores and three main winding assemblies have been shown and described, it is possible to use six main cores and six main winding assemblies for a three phase transformer and to still have the axes of the cores parallel and arranged in a regular order and located at the corners of a regular polygon, and, in other types of electromagnetic devices, to use a different number of cores and winding assemblies provided the symmetry of arrangement is preserved by having the axes of the cores parallel and arranged at the corners of a regular polygon.

Although this invention has been described in considerable detail, it is to be understood that such description is intended as illustrative rather than limiting, as the invention may be variously embodied and is to be interpreted as claimed.

I claim:

1. The method of making a three phase trans-

former comprising forming three closed cores of wound magnetic ribbon each core having a pair of straight leg portions, clamping the straight leg portions of each core and turning the clamped straight leg portions to place the planes of the ribbon in one straight leg portion at an angle to the planes of the ribbon in the other straight leg portion for each core and allowing the end portions to arch outwardly at each end of each core, annealing the cores while they are clamped and while the straight leg portions for each core are held in their angular relation to each other, assembling the cores with the outer faces of adjacent cores arranged back to back, and winding three conducting winding assemblies around the straight leg portions of the cores with each winding assembly surrounding a straight leg portion of each of two adjacent cores.

2. The method of making a three phase transformer comprising winding three closed cores of magnetic ribbon with each core formed of a plurality of sections, each section being of a different width from the preceding section and each section having two straight leg portions joined by end portions, clamping the straight leg portions of each core and turning the clamped straight leg portions to place the planes of the ribbon in one straight leg portion at an angle to the planes of the ribbon in the other straight leg portion for each core and allowing the end portions to arch outwardly at each end of each core, annealing the cores while they are clamped and while the

straight leg portions for each core are held in their angular relation to each other, assembling the cores with the leg portions of adjacent cores arranged back to back so that the leg portions of adjacent cores will form a core having a cruciform cross-section, and winding three circular conducting winding assemblies around the straight leg portions of the cores with each conducting winding assembly surrounding a leg portion of each of two adjacent cores.

3. The method of making a three phase transformer comprising forming three closed cores of wound magnetic ribbon each core having a pair of straight leg portions, clamping the straight leg portions of each core and turning the clamped straight leg portions to place the planes of the ribbon in one straight leg portion at an angle to the planes of the ribbon in the other straight leg portion for each core and allowing the end portions to arch outwardly at each end of each core, annealing the cores while they are clamped and while the straight leg portions for each core are held in their angular relation to each other, assembling the cores with the straight leg portions of adjacent cores arranged in close proximity to each other and in parallelism, and winding three conducting winding assemblies around the straight leg portions of the cores with each winding assembly surrounding a straight leg portion of each of two adjacent cores.

ARTHUR R. WOOLFOLK.