

March 13, 1951

D. E. WIEGAND

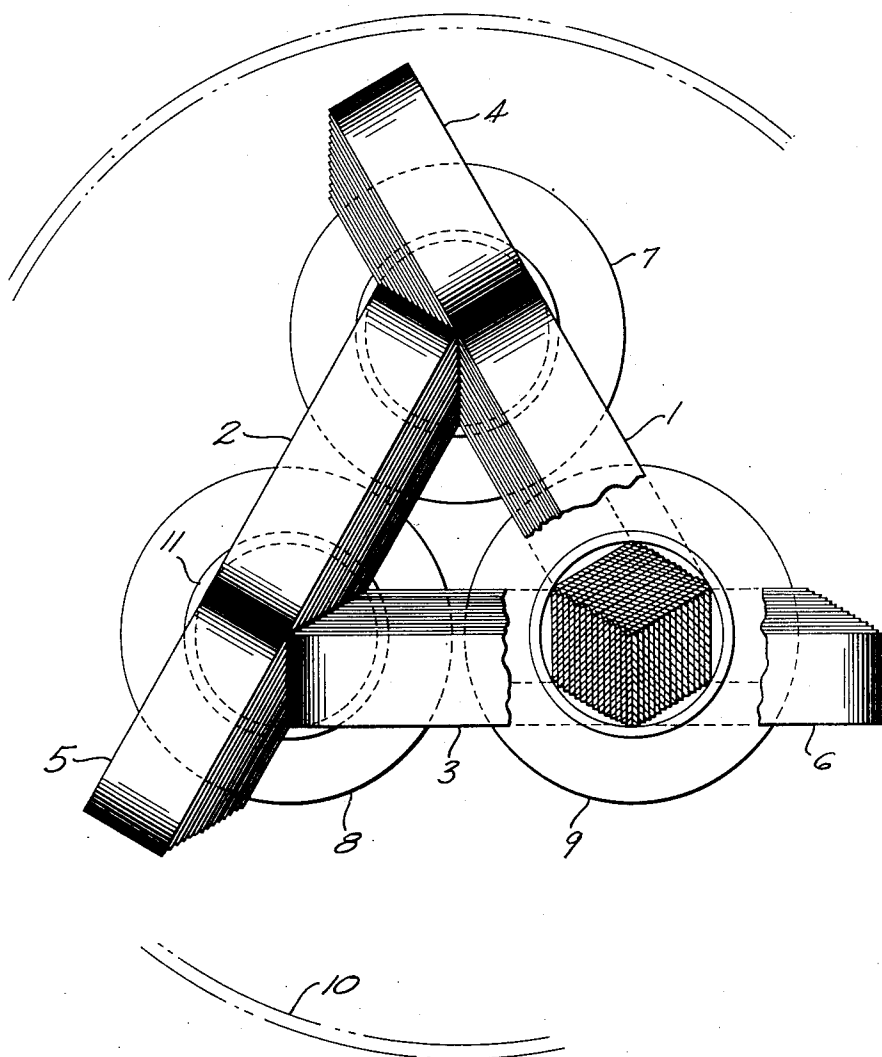
2,544,871

THREE-PHASE TRANSFORMER

Filed April 24, 1947

5 Sheets-Sheet 1

Fig. 1.



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2,544,871

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5 Sheets-Sheet 2

Fig. 2.

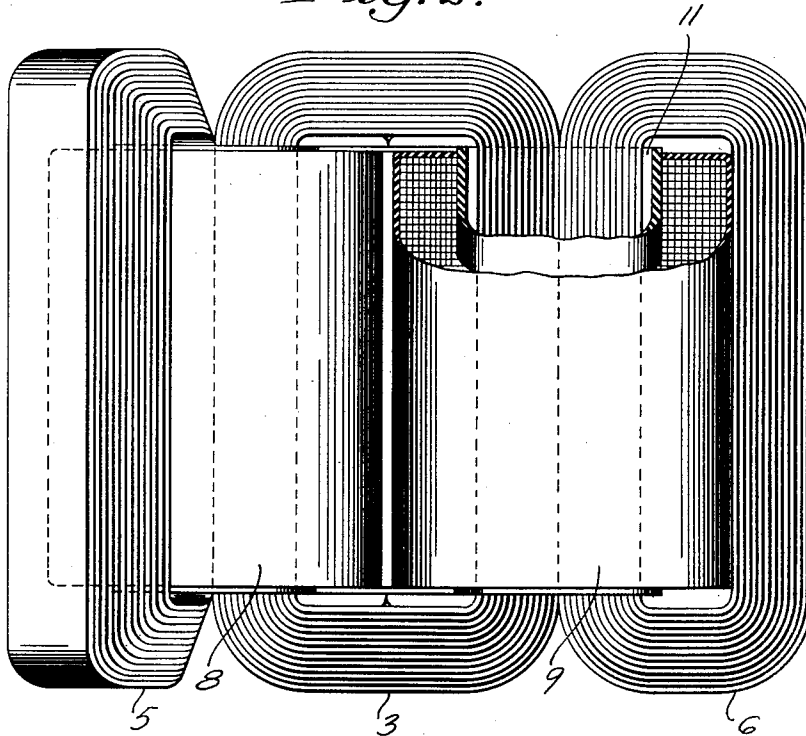
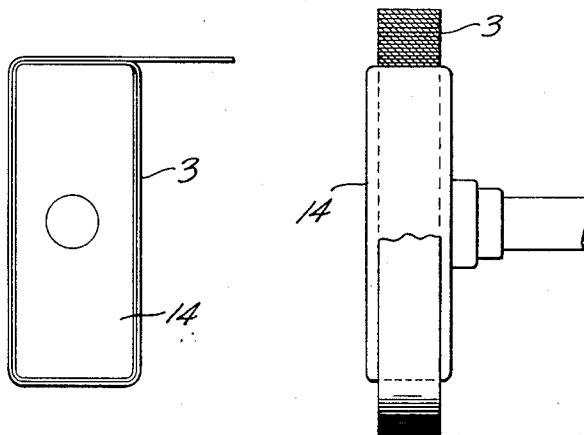


Fig. 3.

Fig. 4.



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5 Sheets-Sheet 3

Fig. 5.

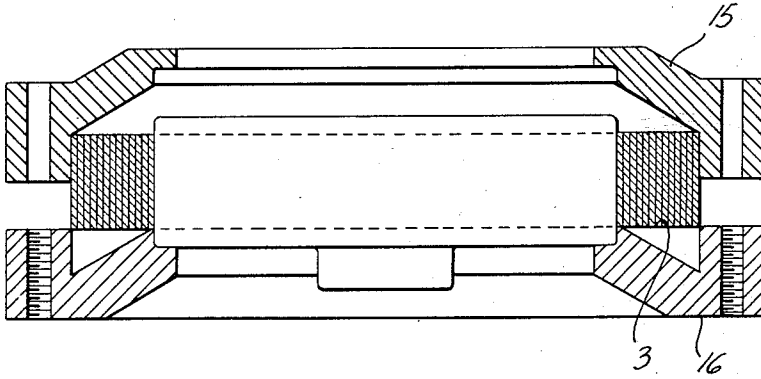


Fig. 6.

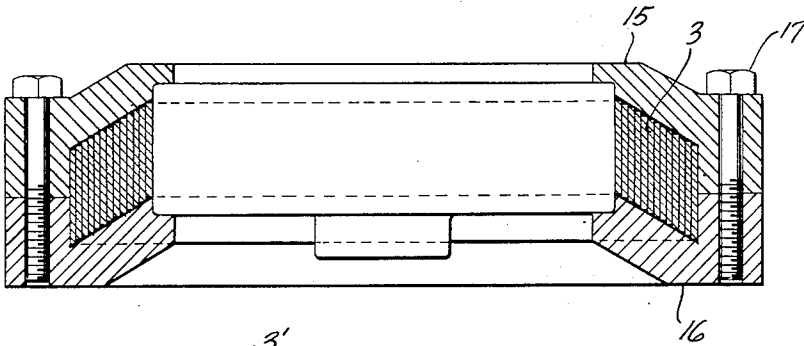
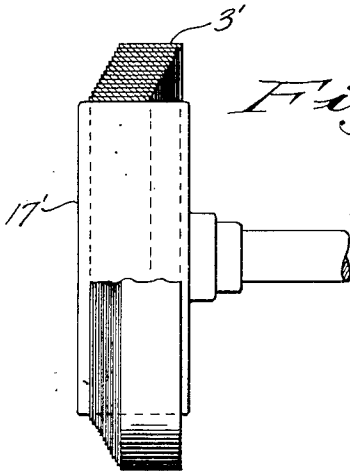


Fig. 7.



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THREE-PHASE TRANSFORMER

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5 Sheets-Sheet 4

Fig. 8.

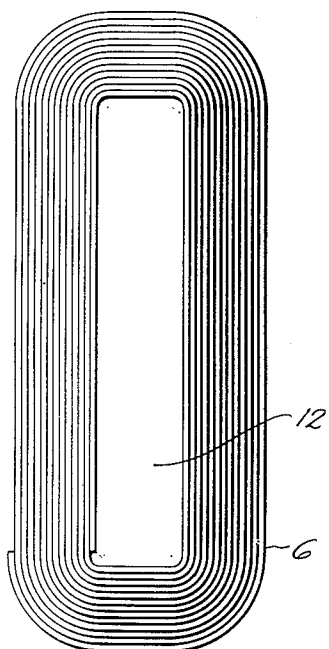


Fig. 9.

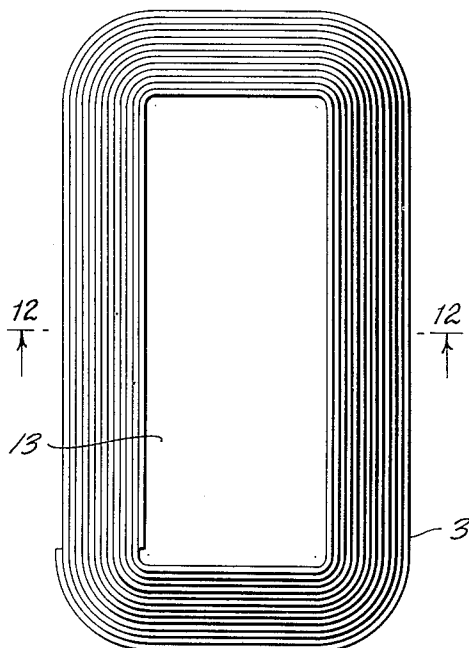


Fig. 10.

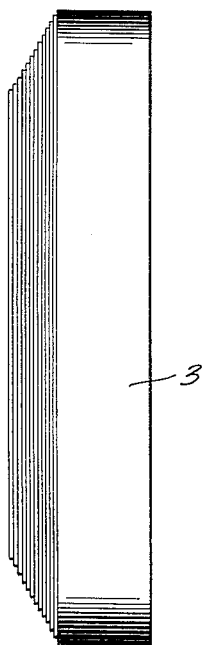
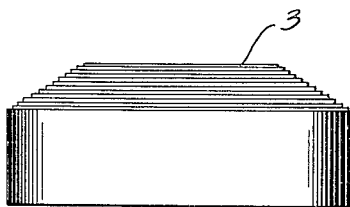


Fig. 11.



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2,544,871

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5 Sheets-Sheet 5

Fig. 12.

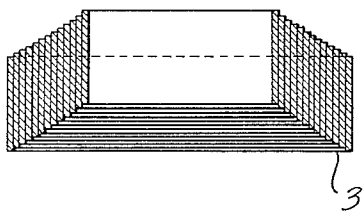


Fig. 13.

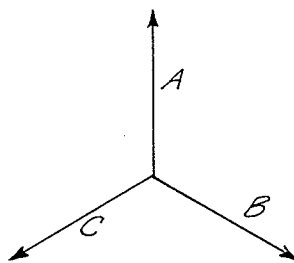


Fig. 14.

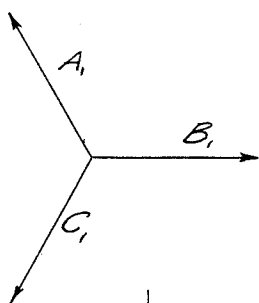


Fig. 15.

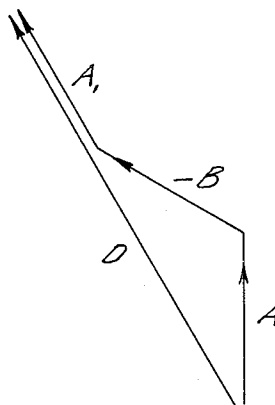
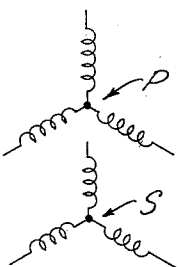


Fig. 16



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UNITED STATES PATENT OFFICE

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THREE-PHASE TRANSFORMER

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Application April 24, 1947, Serial No. 743,568

1 Claim. (Cl. 175—356)

1

This invention relates to three phase transformers and is particularly directed to the core construction for a three phase transformer.

In three phase transformers where the cores are formed of wound magnetic ribbon, it has been found extremely difficult to adequately provide for the transfer of flux from one core section to another core section even where a skew type wound core construction is employed, as shown in my copending application, Serial No. 556,546 filed September 30, 1944, for Three Phase Transformers, which is now abandoned. This limitation in the path of flux which prevented all of the flux through one conducting winding assembly from getting into another conducting winding assembly without part of the flux transferring from one core section to another core section produced a certain amount of core loss. My above noted copending application is owned by the same assignee as that of the present application. In my above noted prior application, the transformer was made by winding three closed cores of magnetic ribbon and skewing or staggering the three successive layers of magnetic ribbon in these core sections so that there was substantially an edge to edge contact between the laminations of the successive cores where they pass through the conducting winding assemblies. In order to adequately fill the circular windows in the conducting winding assemblies, it was necessary, as shown in the above copending application, to use different widths of magnetic ribbon.

Objects of this invention are to provide a construction of a three phase transformer core which will materially reduce the three phase core loss due to flux path limitations in the heretofore known types of three phase wound core transformers, of which my copending application hereinabove noted is an example.

A further object of this invention is to provide a core construction of such a nature that it is possible to use the same width of magnetic ribbon in winding the several cores and yet to so arrange and form these cores that they substantially fill the circular windows through the conducting winding assemblies.

One way of reducing the core loss in a three phase transformer is to use the Y or zig-zag connections exclusively in both the primary and secondary windings of the transformer. This connection allows the induced secondary voltage in the three conducting winding assemblies to contain third harmonic components which will peak the induced voltage wave and which will

2

flatten the flux wave through the core. Therefore, it is clear that for a given value of induced or secondary voltage the peak flux value is less and the core loss is less than would be the case had a delta connection been used. This distorted wave shape of voltage due to the presence of the third harmonic components does not appear between secondary lines since the third harmonic components cancel out. It is to be noted also that if a zig-zag connection is used the voltage from the lines to neutral is not distorted. Even if a Y or zig-zag connection is used the advantages in reduction of core loss is not obtained in the prior types of three phase transformers which are enclosed in a tank for the tank surrounds the transformer fairly closely and tends to produce the effect of a delta connection or a delta tertiary circuit which increases the core loss for a given induced secondary voltage. The delta effect of the tank is due to its electrical conducting properties. In addition to this, there is a further loss due to the magnetic properties of the tank. Any stray flux which gets into the tank wall will cause hysteresis and eddy current losses in the tank which will increase the stray losses of the transformer.

This invention has a still further object of eliminating the harmful effect of the surrounding tank, which tank is composed of magnetic material. The invention provides means whereby auxiliary flux paths are provided for each of the several conducting winding assemblies without having these auxiliary flux paths interlink more than a single conducting winding assembly, the main body of the core construction, however, providing for the interlink of flux for all of the conducting winding assemblies. In other words, this invention has a further object, not only the provision in a wound core type transformer for the interlinking of flux between the several conducting winding assemblies, but also provides independent flux paths of low reluctance which provides a free path for any flux that would have passed to the surrounding tank and in this manner makes it possible to get the full effect of reduced core loss where a Y or zig-zag connection is used for both the primary and the secondary.

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

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

Figure 2 is a view looking from one side of the transformer.

3

Figure 3 is a view showing the manner in which the ribbon is wound.

Figure 4 is a side view of the structure shown in Figure 3.

Figure 5 shows the ribbon after it has been wound and in position between dies.

Figure 6 shows the manner in which the ribbon is staggered or skewed by clamping the dies together.

Figure 7 is a view showing another method of winding the ribbon, such view showing a ribbon being wound in a staggered or skewed manner.

Figure 8 is a face view of an auxiliary core.

Figure 9 is a face view of a main core.

Figure 10 is a side elevation of Figure 9.

Figure 11 is a top view of Figure 9.

Figure 12 is a sectional view on the line 12—12 of Figure 9.

Figure 13 is a vector diagram showing the fluxes common to two coils.

Figure 14 is a vector diagram showing the fluxes linking only one coil.

Figure 15 is a vector diagram showing the total fluxes in one coil.

Figure 16 is a diagrammatic view showing a Y—Y connection of the conducting winding assemblies.

Referring to the drawings, it will be seen that three main cores have been indicated by the reference characters 1, 2, and 3 and the three auxiliary cores by the reference characters 4, 5, and 6. The conducting winding assemblies are indicated by the reference characters 7, 8, and 9 and the tank by the reference character 10.

In making the transformer the conducting winding assemblies are wound in place and are circular and have circular windows indicated in Figure 2 by the reference character 11. The conducting winding assemblies, in each instance, include a primary and a secondary. The primary windings are indicated in Figure 16 by the reference character P and the secondary windings by the reference character S. It is preferable to connect the primary and secondary both in Y relation or in zig-zag relation for a reason hereinafter to appear. Though this invention, in its broadest aspects, is not limited to either of these connections for if desired delta connection could be used though it is preferable to use the other type of connections hereinabove set forth.

The main cores and the auxiliary cores are each formed in exactly the same manner though it is noted from a comparison of Figures 8 and 9, which show respectively an auxiliary core and a main core that the rectangular windows 12 and 13 in the auxiliary and main cores are of different sizes, the window 12 of the auxiliary core being materially smaller than the window 13 of the main core. The reason for this is that the main core interlinks two conducting winding assemblies and the auxiliary core links only one conducting winding assembly. This is shown very clearly in Figures 1 and 2.

In forming the cores, one has been selected, namely one of the main cores, for instance the core 3. This core is shown as being wound on a rectangular mandrel 14 in Figures 3 and 4. This winding continues until the requisite cross-sectional area has been obtained. The magnetic ribbon is then, together with its core, placed between an upper and a lower die 15 and 16, respectively, and skewed or staggered by forcing the two sections of the die together in any suitable manner, as by means of the bolts 17, see Figure 6.

4

Thereafter the core and mandrel are removed from the die and are thoroughly annealed without any further working whatsoever. After this annealing process, the cores are merely assembled as shown in Figures 1 and 2, and the conducting winding assemblies are then wound on the leg sections formed jointly in each instance of two main cores and one auxiliary core. There is, therefore, no stress whatsoever imparted to the cores after they have been annealed as there is no working, bending, or machining of any kind. This is necessary for it has been found that even a slight mechanical strain in the core sections increases the losses in the actual operation of the transformer.

It is obvious that the core sections could be formed as shown in Figure 7 by winding them in a staggered relation on the mandrel 17 and omitting the subsequent step of staggering or skewing them by means of dies shown in Figures 5 and 6.

The circular conducting windings are wound in place on the composite legs formed of the two main cores and the auxiliary core in each instance. Any suitable means may be used for winding the conducting winding assemblies after the cores have been assembled. For example, 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 could be used.

The vector diagram for the fluxes in the main cores are indicated by the reference characters A, B, and C in Figure 13, while the vector diagram for the fluxes in the auxiliary cores are shown at A₁, B₁, and C₁ in Figure 14. The combined flux interlinking any given conducting winding assembly is indicated at D in Figure 15. It will be seen that this vector D is arrived at by subtracting the vector B from the vector A and adding the vector A₁ of the auxiliary core.

This invention is an improvement over that disclosed in my copending application hereinabove noted and it is designed to materially reduce the core losses even over that for a transformer built in accordance with the disclosure of my above noted copending application. The core loss in the three phase transformer is reduced when a Y or zig-zag connection is used for both the primary and the secondary of the transformer. This connection permits induced secondary voltage in the three coils to contain third harmonic components which peak the induced voltage wave. However, this third harmonic flattens the flux wave. Therefore, for a given value of induced voltage the peak value of the flux is less and consequently the core loss is less. Further it is to be noted that by using a Y connection or a zig-zag connection the third harmonic does not appear between lines as the third harmonics are cancelled out. If a zig-zag connection is used, the voltage from lines to neutral does not have the third harmonic.

It has been found that where a wound core type of transformer is constructed in accordance with the disclosure of my above noted copending application that the tank which encircles the transformer acts like a delta connected winding or a tertiary delta connected winding and, therefore, the advantages of the Y or zig-zag connection in reducing the core loss for a three phase transformer is not obtained. However, by providing the auxiliary cores which furnish a very low reluctance flux path independent of the common flux paths for each conducting winding assembly, the undesirable effect of the tank wall

is avoided. It is, therefore, possible to use a Y connection or zig-zag connection and obtain the maximum reduction in core loss as all of the advantages of a Y connection or zig-zag connection are obtained though the transformer is surrounded by the tank. In addition to this, the losses due to the magnetic properties of the tank are avoided, as practically no stray flux gets into the tank wall.

Another very pronounced advantage is obtained by the peculiar manner in which the main and auxiliary cores are staggered or skewed and are associated with each other. It is to be noted that the main cores 1, 2 and 3 are all staggered inwardly and the adjacent edges of the magnetic ribbon are positioned in close juxtaposition or substantial edge to edge contact with each other. The auxiliary cores are also staggered or skewed and their tapered or staggered edges are positioned adjacent or in substantial contact with the flat face of the main core, whereas, their flat faces are arranged in back to back relation with another of the main cores. Thus it will be seen from an examination of Figure 1 that each auxiliary core lies in the same general plane as the corresponding main core and a symmetrical arrangement of cores is obtained. The arrangement is such that although the same width of magnetic ribbon is used throughout for both the main and auxiliary cores, nevertheless, a hexagonal cross-sectional contour is obtained for the composite leg formed of two main cores and the auxiliary core where it passes through a conducting winding assembly. In this way, an excellent space factor is obtained which compares very favorably with the previously used cruciform cross-sections for wound magnetic cores. It is, of course, apparent that if desired, sections of different widths could be employed for the magnetic ribbon, but only a very slight gain in space factor would be obtained which would not warrant the additional expense necessitated by the use of different widths of ribbons. Instead of the additional expense due to using different widths, ribbons of a single width are used throughout as stated hereinabove and yet an excellent space factor is obtained.

The expression "star" connected as used in the claims hereinafter appended is intended to cover either a Y connection or a zig-zag connection of the conducting winding assemblies and is used to distinguish from a delta connection.

It is to be noted particularly that each of the adjacent pairs of main core sections when combined with an auxiliary core section form jointly

a winding leg about which the conducting winding assembly is wound as described in detail hereinbefore. The construction readily lends itself to winding circular conducting winding assemblies around the winding leg as each core section has straight leg portions which, as stated hereinabove, form jointly the winding legs of the transformer.

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:

A three phase transformer comprising three conducting winding assemblies, three main cores and three auxiliary cores, the three main cores being arranged in the shape of a triangle, each of the three main cores interlinking only two conducting winding assemblies, a metal tank surrounding said transformer, said conducting winding assemblies having a star connected primary and a star secondary winding, the auxiliary cores each linking a single and a different conducting winding assembly and providing independent flux paths of low reluctance and arranged to prevent the delta effect of the surrounding tank, the portions of said main cores which interlink a common winding assembly having a substantially edge-to-edge contact with each other and the auxiliary cores each having a substantially edge-to-face contact and a back-to-back contact with the adjacent main cores.

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