C. E. LEE.

TRANSFORMER.

APPLICATION FILED SEPT. 10, 1917.

1,390,050.

Patented Sept. 6, 1921.

2 SHEETS—SHEET 1.

Fig. 1.

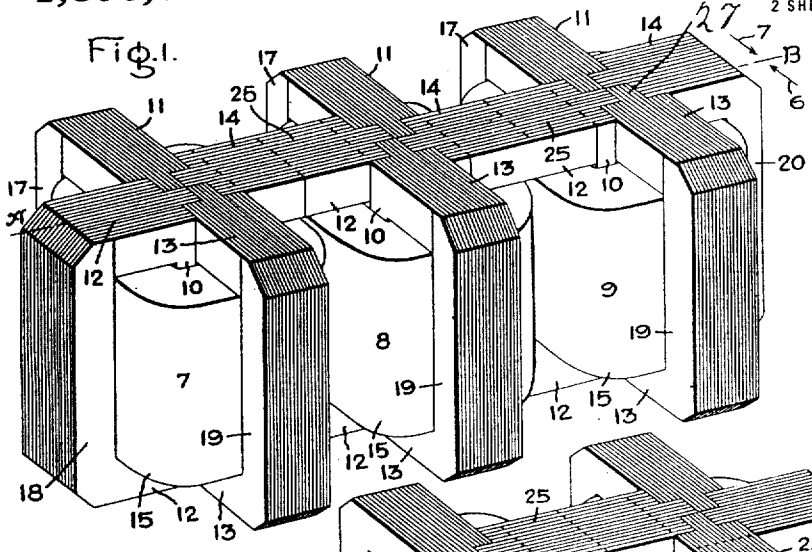



Fig. 2.

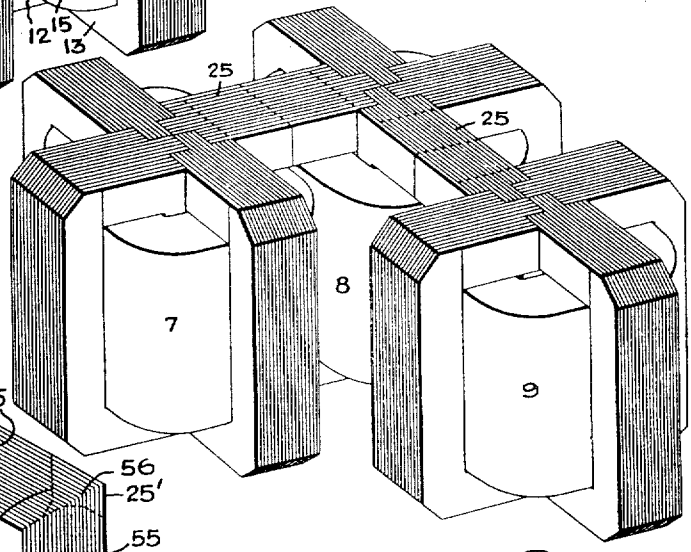



Fig. 4.

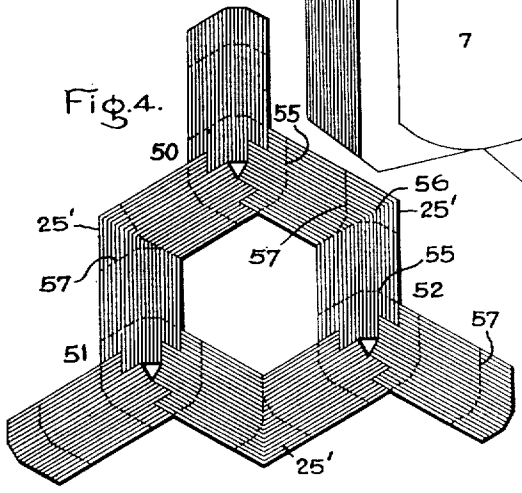



Fig. 5.

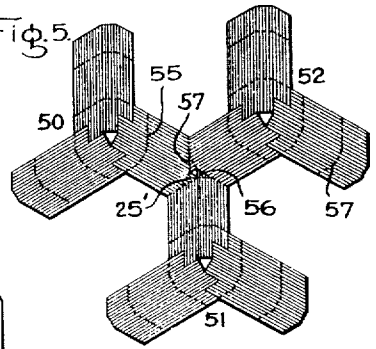
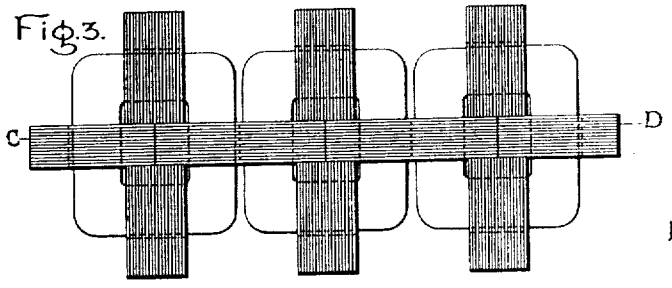



Fig. 3.




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2 SHEETS—SHEET 2.

Fig.6.

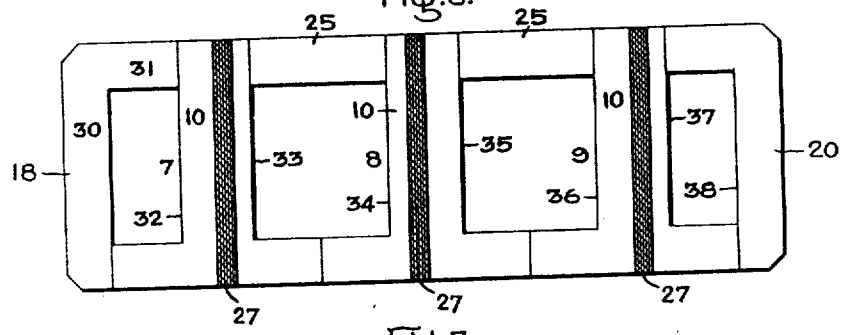



Fig.7.

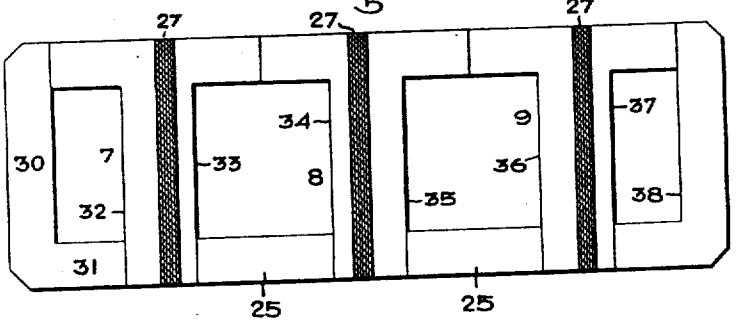



Fig.8.

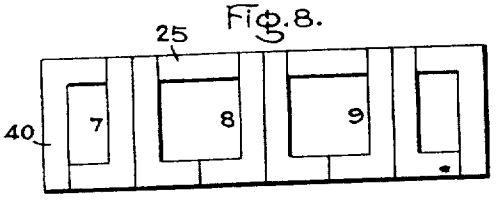



Fig.10.

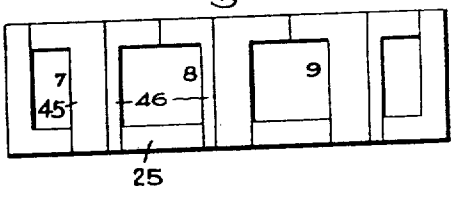



Fig.9.

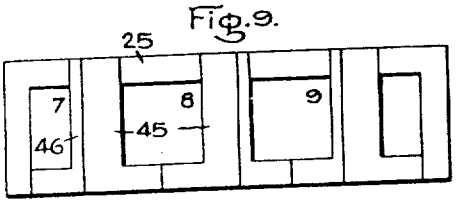
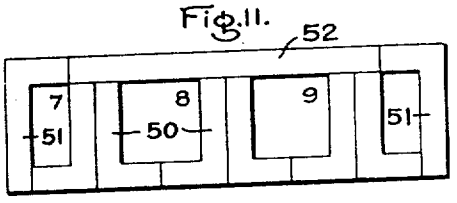



Fig.11.




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# UNITED STATES PATENT OFFICE.

CORLISS E. LEE, OF PITTSFIELD, MASSACHUSETTS, ASSIGNOR TO GENERAL ELECTRIC COMPANY, A CORPORATION OF NEW YORK.

## TRANSFORMER.

1,390,050. Specification of Letters Patent. Patented Sept. 6, 1921.

Application filed September 10, 1917. Serial No. 190,419.

*To all whom it may concern:*

Be it known that I, CORLISS E. LEE, a citizen of the United States, residing at Pittsfield, in the county of Berkshire, State of Massachusetts, have invented certain new and useful Improvements in Transformers, of which the following is a specification.

My invention relates to polyphase transformers, reactors and other analogous devices, and one object of my invention is to provide an improved polyphase device of this nature. A more particular object of my invention is to provide a polyphase transformer which may be constructed of substantially the same parts as are used in single phase transformers of the so-called "distributed core" type. The so-called "distributed core" type of single phase transformer is well known and for the present purposes may be defined as a transformer comprising a single inner core leg carrying the winding and a plurality, generally three or four, outer core legs and corresponding yokes completing independent magnetic circuits through the winding leg. Another more particular object of my invention is to provide a polyphase transformer in which one or more phases of the system may be opened without affecting the operation of the other phase or phases.

Preferably in carrying out my invention I employ substantially a distributed core single phase transformer for each of the phases of the system on which the transformer is used, omitting one or more of the outer legs of each of the single phase parts or transformers and joining together yokes of different transformers corresponding to omitted legs so as to magnetically couple the different transformers to some extent. Preferably I retain such of the outer legs of each of the single phase transformers as correspond to yokes not required for magnetically coupling the transformers. By thus employing substantially the same parts, and to some extent the same assembly of parts, as are used for single phase transformers, I am able to reduce the costs, and by employing something of the distributed core type of construction I secure in polyphase transformers something of the advantages heretofore secured in single phase transformers by the distributed core construction; and further by employing one or more independent magnetic return circuits with each winding leg, each phase is to that extent independent of the other phase or phases and the polyphase transformer is better able to operate on a part only of all the phases when the other electrical circuit or circuits are disconnected or open; the two latter advantages of my invention can be obtained of course even though the polyphase transformer is not made up of single phase transformer parts. It is possible by my invention to provide a three phase transformer of substantially balanced magnetic circuits as appears hereinafter.

In the accompanying drawing and the following description I have illustrated and described in some detail the best embodiments of my invention of which I am now aware. Figure 1 is a perspective view of a preferred form of my invention embodied in a three phase transformer. Fig. 2 is a perspective view of a modification of the construction of Fig. 1. Fig. 3 is a plan view of a three phase transformer embodying another form of the distributed type of core commonly found in single phase transformers. Figs. 4 and 5 are plan views of three phase transformers embodying still another form of single phase distributed core transformer construction; the arrangements of the single phase parts are also different from anything illustrated before. Figs. 6 and 7 are elevations of adjacent layers of laminations of the transformer of Fig. 1. Fig. 8 is an elevation of a lamination layer of the transformer of Fig. 3. Figs. 9 to 11 are elevations of layers of laminations of transformers resembling that shown in Fig. 3.

The three phase transformer of Fig. 1 is made up, substantially, of three single phase parts or transformers 7, 8 and 9, each of which is substantially like that shown in Figs. 1 and 2 of the drawing of the patent to Hall #861,029, July 23, 1907, except that the core of each is made up of L-shaped lamination sections instead of U and rectangular shaped sections as in that patent. Each L-shaped lamination section comprises a leg portion disposed in a leg of the core

and a yoke portion disposed in a yoke of the core, and the lamination layers comprising these sections are alternately reversed (or reversed in groups of a small number of layers per group), top and bottom, to break joints, as may be understood from the later consideration of Figs. 6 and 7. These transformers comprise a number of core-sections for each single phase part as appears from the drawings and as may be more completely understood from the above Hall patent, these sections interlocking to provide each of these transformers or parts 7, 8 and 9 with a central winding leg 10 and four yoke members 11, 12, 13 and 14 at each end of the winding leg 10. This form of construction is well known and need be no further described. The winding legs 10 carry the windings 15. In the single phase part or transformer 7 of Fig. 1 of the drawing of the specification the two yokes 11 are joined by an outer leg 17; likewise the two yokes 12 are joined by an outer leg 18 and the yokes 13 by an outer leg 19. The leg normally joining the two yokes 14 of the transformer 7 (that is the leg that would be found joining the yokes 14 if the part 7 comprised a complete single phase transformer as may be understood from the above Hall patent) has been omitted as appears from Fig. 1 of the present drawing; this outer leg has been omitted by omitting or taking away all the L-shaped lamination sections, the leg portions of which normally comprise this outer leg. The omission of these lamination sections results in the creation of spaces in the yoke members 14; these spaces are filled by the interleaved laminations or lamination sections 25 which are later referred to in more detail. The single phase part 9 of Fig. 1 is similar to the part 7 except that the leg 18 joining the yokes 12 has been omitted and the yokes 14 are joined by the usual outer leg 20. In the single phase part 8 of Fig. 1 the two yokes 11 are joined by the usual outer leg 17 and the two yokes 13 are joined by the usual outer leg 19; but both of the legs usually joining the yokes 12 and the yokes 14 have been omitted. The three single phase parts 7, 8 and 9 are so assembled together that the outer ends of the yokes corresponding to each omitted leg of each transformer are adjacent the outer ends of yoke members corresponding to an omitted leg of another transformer; that is, the outer ends of the yokes 12 of the single phase part or transformer 8 are assembled adjacent the outer ends of the yoke members 14 of the single phase part or transformer 7, and likewise the outer ends of the yoke members 12 of the single phase part or transformer 9 are assembled adjacent the outer ends of the yoke member 14 of the single phase part or transformer 8. Further the single phase parts or transformers are so assembled that the spaces in the different adjacent yoke members which occur by reason of the omission or taking away of the L-shaped lamination sections of the omitted legs, are disposed opposite each other, and these spaces are filled by interleaved laminations or lamination sections 25 of a rectangular shape as before indicated. In order to illustrate this assembly, the laminations of the transformer of Fig. 1 are shown as of much greater thicknesses than is usual in practice. In the transformer of Fig. 1 the L-shaped lamination sections are illustrated as assembled and reversed in pairs, hence the interleaved laminations or lamination sections 25 are inserted in pairs. The assembly of the lamination sections of this transformer of Fig. 1 may be more easily understood from a consideration of Figs. 6 and 7.

Fig. 6 is a section taken on the line A—B of Fig. 1 between two layers, looking in the direction of the arrow 6; Fig. 7 is a section on line A—B of Fig. 1 looking in the direction of the arrow 7; hence Figs. 6 and 7 illustrate adjacent lamination layers. The vertical lined cross-sectioned parts 27 of Figs. 6 and 7 represent in cross-section the intermeshing ribs 27 (see Fig. 1) of the winding legs corresponding to the yoke members 13. Since these yoke members 13 and their corresponding outer legs 19 (like the yoke members 11 and the corresponding outer legs 17) are unchanged in the construction of the three phase transformer, no further notice need be taken of them. The remaining parts of Figs. 6 and 7 illustrate adjacent laminations and as appears from the location of the line A—B on Fig. 1, illustrate laminations which are reversed, top and bottom, with respect to each other. Referring first to the lamination layer of Fig. 6; an L-shaped section 30 having a wide leg portion and with its yoke portion 31 uppermost, coöperates with and at its ends butts against another L-shaped lamination section 32 also having a broad vertical leg (forming a part of the winding leg 10 of the part 7) but with its yoke portion at the bottom of the figure. These two lamination sections 30 and 32 complete one of the lamination layers of the section of the single phase transformer 7 comprising the outer leg 18, and this construction is the same whether the single phase part 7 is used as a single phase transformer (with the addition of the usual leg joining yokes 14) or whether this single phase part 7 comprises a part of the three phase transformer illustrated in Fig. 1. The inner edge of the lamination section 32 abuts of course against the intermeshed rib 27 as shown both in Fig. 1 and in Fig. 6; at the opposite side of this rib 27 is located the usual L-shaped section 33. This L-shaped section however has a narrow

vertical leg (since this single phase section 7 is substantially similar to the construction shown in the above mentioned Hall patent), also forming a part of the winding leg 10 of the single phase part 7; the yoke portion of the lamination section 33 is at the bottom of the figure. In the single phase transformer or part 8 is a lamination section 34 corresponding to the lamination section 33, that is having a narrow vertical leg and a yoke portion at the bottom of the figure; the two yoke portions of the sections 33 and 34 abut as illustrated in Fig. 6. Between the upper ends of the vertical legs of the sections 33 and 34 is one of the interleaved rectangular laminations or lamination sections 25. As appears from Fig. 6 this lamination section 25 and the lamination sections 33 and 34 complete a magnetic circuit through the winding legs 10 of the single phase parts or transformers 7 and 8 so that these two single phase parts or transformers are magnetically interlinked thereby. The usual lamination sections 35 and 36 of the parts 8 and 9 are related in the same manner as the lamination sections 33 and 34 and as appears from Fig. 6; that is, the lower yoke portions abut each other and a rectangular lamination section 25 joins the upper ends of the vertical legs 35 and 36. Following the construction described in the Hall patent the lamination sections 35 and 36 have broad vertical leg portions. The outer section of the transformer part 9 comprising the outer leg 20, comprises the usual lamination sections 37 and 38 arranged quite like the sections 30 and 32. It should be observed that the lamination sections 25 and the assembly together of the parts 33 and 34 and the parts 35 and 36 not only result in magnetically connecting the winding leg of the transformer part 8 with the winding leg of the transformer part 7 and the winding leg of the transformer part 8 with the winding leg of the transformer part 9, but also the winding leg of the transformer part 7 is magnetically connected with the winding leg of the transformer part 9 thereby. As before mentioned and for well-known reasons, such as to secure better magnetic action and greater mechanical strength, the lamination layers of the transformer of Fig. 1 are reversed in pairs, top and bottom, to break the joints; that is, two lamination layers similar to Fig. 6 are located adjacent each other, then against one of these are located two similar layers reversed top and bottom, then two unreversed lamination layers against these latter, etc., as may be observed in Fig. 1. A reversed lamination layer is illustrated in Fig. 7. The lamination sections of Fig. 7 bear the same reference numerals as the lamination sections of Fig. 6 and these lamination sections are similarly assembled except for the reversal top and bottom. This reversal will be understood from a comparison of Figs. 6 and 7. A comparison of these two figures shows that the lower parts of the lamination sections shown in Fig. 6 appear as upper parts in Fig. 7; and likewise the upper parts of the sections of Fig. 6 are the lower parts in Fig. 7. Thus the yoke portions of the lamination sections 33 and 34 abut each other at the bottom of Fig. 6 and at the top of Fig. 7; correspondingly, the lamination sections 25 of Fig. 7 are at the bottom of the figure rather than at the top of the figure as in Fig. 6. It appears from this that when the lamination layers of Fig. 7 is applied against the face of the lamination layer of Fig. 6, each lamination section 25 lies against and spans the joint between yoke portions of lamination sections 33 and 34, or between 35 and 36.

It thus appears that the three phase transformer of Fig. 1 is substantially made up of parts of and of substantially the same assembly of these parts of, three similar single phase distributed core transformers (7, 8 and 9), these single phase transformers being modified substantially only by omitting the L-shaped lamination sections (similar to 30 and 38 of Figs. 6) corresponding to one outer leg of each of the single phase transformers 7 and 9 and two outer legs of the single phase transformer 8, lamination sections 25 being interleaved into the yokes 12 and 14 at the spaces created by the omission of the yoke portions of the omitted lamination sections.

The three phase transformer of Fig. 2 is substantially similar to that of Fig. 1 except that the two outer single phase parts or transformers 7 and 9 engage the part or transformer 8 at adjacent core sections rather than at opposite core sections as in Fig 1; this results in producing a three-phase transformer which has generally a triangular outline rather than the generally rectangular outline of the transformer of Fig. 1. The transformer of Fig. 2 further is distinguished from the transformer of Fig. 1 in that the lamination layers are reversed individually and alternately rather than alternately in pairs as in the transformer of Fig. 1. The adjacent yoke members corresponding to the omitted legs of the different transformers are joined by interleaved lamination sections 25 as in the construction of the transformer of Fig. 1. The construction of the transformer of Fig. 2 will be understood without further description.

The three-phase transformer, the plan view of which is shown in Fig. 3, is quite similar to that shown in Fig. 1 except the three single phase parts or transformers are of a different form. These single phase parts or transformers are of the general con-

struction disclosed in the patent to Hall #755,766, March 29, 1904, except that the cores are made up of L-shaped punchings rather than of the U-shaped and rectangular punchings illustrated in that Hall patent. As before indicated with respect to the parts of the polyphase transformer of Fig. 1, the construction of these single phase transformers from L-shaped punchings is well-known. Fig. 8 shows in elevation one lamination layer taken on the line C—D of Fig. 3. It will be observed that this lamination layer is composed of L-shaped lamination sections 40 and interleaved rectangular sections 25 which are assembled in substantially the same way as in Fig. 6; of course, since the four core sections of the core of each single phase part do not intermesh or interlock, ribs 27, such as appear in Fig. 6, do not appear in Fig. 8. The lamination layers are reversed, top and bottom (as the lamination layers of Fig. 6 are reversed individually or in groups) groups of small members of layers as before described. This construction possesses one advantage over the construction of Fig. 1 heretofore described, in that the magnetic flux passing, for example, from the winding leg of the single phase part 7 to the winding leg of the single phase part 9 is required to traverse a smaller number of joints.

In Figs. 9 and 10 are shown in elevation another construction of the lamination layers by which a better magnetic connection is secured in a three-phase transformer quite closely resembling that of Fig. 3. These lamination layers may be substituted in the transformer of Fig. 3 in the place of those illustrated in that figure and in Fig. 8. These lamination layers are also made up of L-shaped sections and rectangular sections but the legs of the sections forming the winding legs are of different widths; thus the lamination section 45 has a larger width of winding leg than the lamination section 46. The adjacent lamination layers are reversed as before in order to break joints but they are reversed not only top and bottom but also end to end. Thus the lamination layer of Fig. 10 is similar to the lamination layer of Fig. 9 except that it is reversed both top and bottom and end and end; in the winding leg of the single phase part or transformer 7, the narrow leg lamination 46 of the lamination layer of Fig. 9 is found to the left of the broad leg lamination section 45 and the yoke portions of these lamination sections are at the bottom of the figure, while in the lamination layer of Fig. 10 the broad leg lamination section 45 is found at the left of the narrow leg section 46 and their yoke portions are at the top of the figure. It will be apparent that when the long longitudinal portion of the three phase transformer core of Fig. 3 is built up of the lamination layers of Figs. 9 and 10 alternating either individually or in small groups, all the joints of the magnetic circuit are broken or bridged and magnetically the core will function better between the different winding legs.

A still further form of lamination layer for substantially such a three-phase transformer as is shown in Fig. 3, is illustrated in elevation in Fig. 11. This lamination layer comprises a plurality of L-shapes 50 assembled substantially as before indicated to form the winding legs and yokes of the single phase parts or transformers 7, 8 and 9. The outer end legs of the cores of the single phase parts or transformers 7 and 9 are made up of L-shapes 51, the legs of which are longer than the legs of the L-shaped sections 50 by the width of the yoke portions of the L-shaped sections. This lamination layer is distinguished from the layers previously described particularly by the long interleaved lamination section 52. As appears from Fig. 11 this interleaved lamination section 52 extends between the ends of the yoke portions of the lamination sections 51 and completely across the ends of the leg portions of the lamination sections 50 forming the three winding legs. Thus at one side of the lamination layer there is an uninterrupted magnetic path connecting the ends of all the winding legs. Such lamination layers are reversed top and bottom as more particularly described with respect to Figs. 6 and 7, these reversals occurring as before either alternately with respect to individual lamination layers or alternately with respect to small groups of lamination layers. By this construction there is a somewhat still better magnetic circuit provided for the magnetic flux passing between the different winding legs.

Figs. 4 and 5 are plans of three-phase transformers embodying other forms of my invention, these polyphase transformers comprising single phase transformers of the sort disclosed in Patent No. 1,282,086 issued in the name of Sven E. Johannesen, on October 22, 1918, particularly those illustrated in Figs. 1 and 2 of the drawing of that application. Since this sort of single phase transformer is clearly described in that co-pending application it is not necessary to further describe it here.

These figures illustrate not only the application of my invention to this particular form of the distributed core type of transformer, but also illustrate how it is possible by my invention to provide a three-phase transformer of substantially balanced magnetic circuits.

Referring first to Fig. 4: In the three-phase transformer construction illustrated in this figure, two of the three outer legs of each single phase part or tranformer 50, 51

and 52 are omitted. The single phase parts or transformers are so disposed with respect to each other that the winding legs are substantially at the apexes of an equilateral triangle and the ends of the yoke members corresponding to the omitted legs of each single phase part or transformer are disposed adjacent ends of yoke members of the other two single phase parts or transformers as appears from Fig. 4. As described in detail with relation to the construction of Fig. 1, interleaved lamination sections $25^1$ are disposed in the spaces of the yoke members of the single phase parts and magnetically connect the winding legs. These interleaved laminations sections $25^1$ extend from substantially adjacent the outer surface 55 of one winding leg to substantially the outer surface 55 of another winding leg, that is completely fill the spaces created by the omission of the outer leg lamination sections. In consequence of the three section form of the single phase transformers and in further consequence of the relative locations of the single phase transformers with respect to each other, the members of each set of interleaved laminations $25^1$, that is, the members of each lot of laminations $25^1$ which join each two certain winding legs, are of a number of different lengths and furthermore are bent at an angle as illustrated at 56; to this extent these interleaved lamination sections $25^1$ differ from the sections 25 of the construction of Fig. 1 and other constructions before described wherein the interleaved lamination sections 25 are of the uniform length and without bends. The dotted lines 57 indicate the outer ends of the yoke portions of the L-shaped lamination sections passing through the winding leg of the single phase transformers, at least under the usual single phase conditions.

The single phase parts or transformers of the three phase construction of Fig. 5 are differently disposed. As before, the winding legs of the three transformers are disposed at the apexes of an equilateral triangle, but in this case only one outer leg of each of the single phase parts or transformers 50, 51 and 52 is omitted. The ends of the yoke members corresponding to the omitted legs of the three single phase parts are disposed adjacent each other at the center of the triangle. As before, interleaved lamination sections $25^1$ are inserted to magnetically join the winding legs. In a manner somewhat similar to that of the construction of Fig. 4 the lamination sections $25^1$ are bent and of varied lengths. It will be observed that each yoke member in the construction of Fig. 5 is directly joined to two other yoke members by means of the interleaved lamination sections $25^1$; this is a distinctive feature of this construction. Various reference characters which appear on Fig. 4 also appear on Fig. 5 and represent the same elements or features.

It should be understood that while in the above and in the following claims I have referred substantially only to transformers, my invention may be embodied in polyphase reactors or other analogous devices, and I aim in the appended claims to include such other devices.

While I have described the principle of my invention and the best mode I have contemplated for applying this principle, other modifications will occur to those skilled in this art and I aim in the appended claims to cover all modifications which do not involve a departure from the spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent in the United States, is:

1. A polyphase transformer comprising substantially a plurality of distributed core transformer elements, yoke members of each of said transformer elements being joined end to end to yoke members of another of said transformer elements.

2. A polyphase transformer composed of a plurality of distributed core type transformer elements, a portion of the core of each of said elements having free yoke members, said yoke members being joined together end to end in the polyphase transformer.

3. A polyphase transformer comprising a plurality of winding legs. windings on each of said legs, yokes and an outer leg completing an individual magnetic circuit for each of said winding legs, and yokes joining said winding legs together.

4. A polyphase transformer composed of a plurality of single-phase distributed core type transformer elements, the core of each element being laminated and having a predetermined number of open and closed magnetic circuits, the open circuited core portions providing yokes with free ends; said yokes of different elements being abutted and joined together end to end in the polyphase transformer.

5. A polyphase transformer composed of a plurality of single-phase distributed core type transformer elements, the core of each element being laminated and having a predetermined number of open and closed magnetic circuits, the open circuited core portions providing yokes with free ends; said yokes of different elements being abutted, and laminated material interleaved therewith whereby said elements are joined together.

6. A three-phase transformer composed of three singe-phase distributed core type transformer elements, the core of each element being laminated and having $n$ mag-

netic circuits $n-2$ only of which in one element are closed, $n-1$ only being closed in the other elements; said elements being united with magnetic material associated with the open circuits whereby said open circuits are closed through adjacent elements.

7. A polyphase transformer comprising a plurality of distributed core type transformer elements and magnetic material uniting said elements arranged whereby said elements have a plurality of magnetic circuits in common.

In witness whereof, I have hereunto set my hand this sixth day of September, 1917.

CORLISS E. LEE.