

1,342,995.

Patented June 8, 1920.

2 SHEETS—SHEET 1.

Fig. 1.

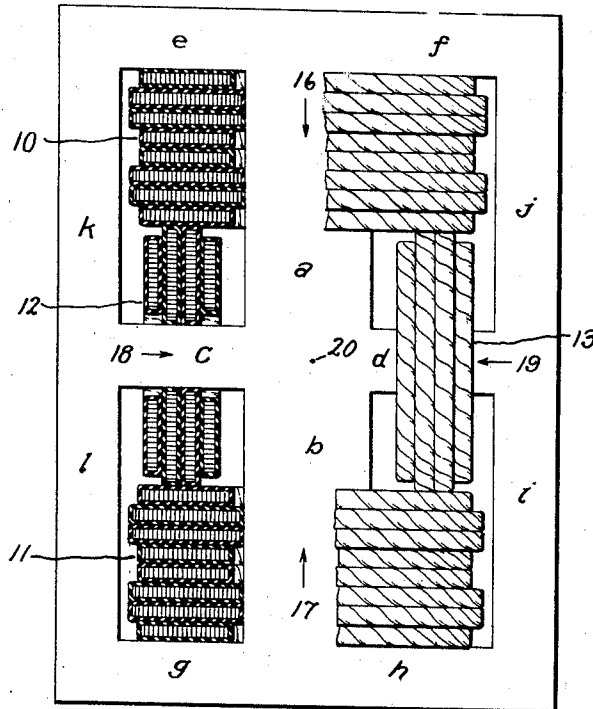


Fig. 2.

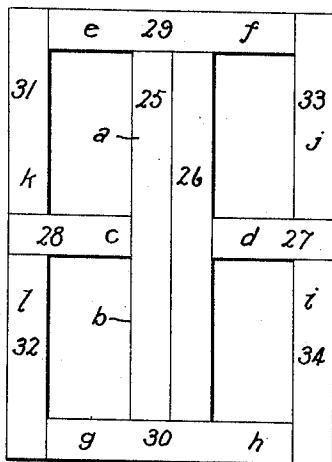
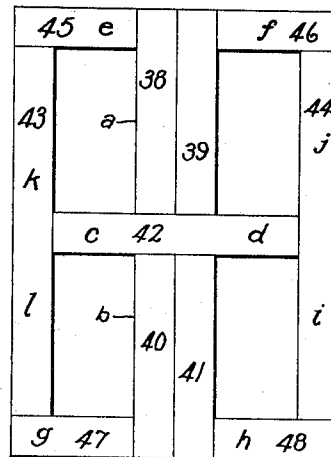


Fig. 3.



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2 SHEETS—SHEET 2.

Fig. 4.

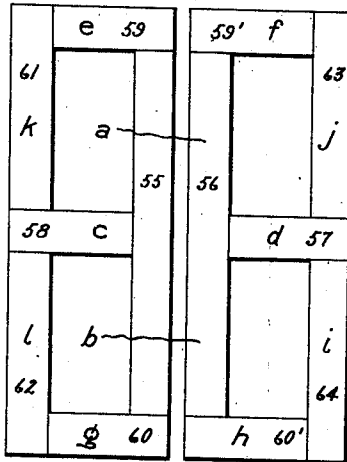


Fig. 5.

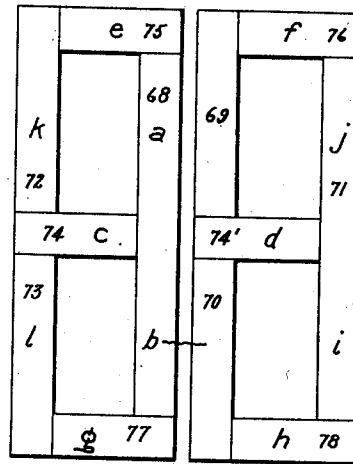


Fig. 6.

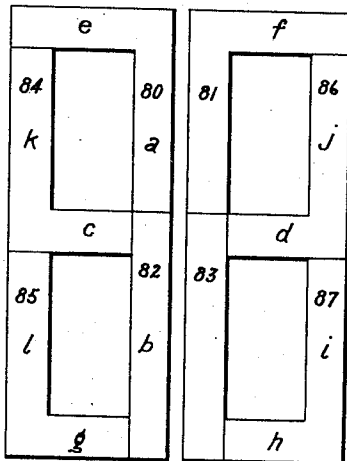
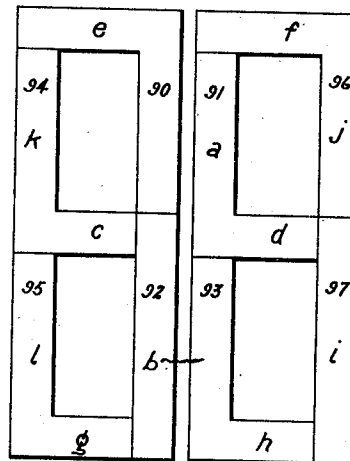


Fig. 7.



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UNITED STATES PATENT OFFICE.

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ELECTRICAL APPARATUS.

1.342.995.

Specification of Letters Patent.

Patented June 8, 1920.

Application filed September 2, 1919. Serial No. 321,044.

To all whom it may concern:

Be it known that I, JOHN J. FRANK, 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 Electrical Apparatus, of which the following is a specification.

My invention relates to induction apparatus and especially to three-phase stationary induction apparatus such as three-phase transformers and three-phase reactances. One object of my invention is to provide a core for induction apparatus which is economic in material and efficient in operation, which exhibits a saving in the labor required in its construction, and which need be taken down in part only to remove any damaged winding or parts of winding. Another object of my invention is to provide a three-phase induction apparatus which is economic in material, which exhibits a saving in the labor required in its construction, and in which the windings of the three-phase are physically quite separate and as little bound together mechanically by the core as may be. Other objects and desirable results of my invention will appear.

My invention can best be understood from the accompanying drawing and following description in which I have illustrated and described in some detail the best embodiment of my invention of which I am now aware. Figure 1 is a plan view, partly in section, of a core and coils of a three-phase transformer embodying my invention. Figs. 2 and 3 are plan views showing the arrangements of the lamination sections in two adjacent laminations, or laminations of different groups, suitable for the core of Fig. 1.

Figs. 4 and 5 are plan views showing the arrangements of laminations when it is desired to provide a central air passage. Figs. 6 and 7 are plan views showing the arrangements of laminations yielding the same results as in Figs. 4 and 5 but assembled from L-shaped laminations.

The core of the transformer of the drawing has two winding legs *a* and *b* joined at their inner ends and extending in opposite directions, and two other winding legs *c* and *d* joining legs *a* and *b* at their juncture and extending in opposite directions from each other and at right angles to the legs *a* and *b*. External members join the outer ends of the

winding legs and thus complete the magnetic circuit. These external members comprise the yokes *e* and *f* from the outer end of leg *a*, yokes *g* and *h* from the outer end of leg *b*, and outer legs *i*, *j*, *k* and *l* between the yokes and the legs *c* and *d* as shown. The winding 10 of one phase, comprising primary and secondary coils, surrounds the winding leg *a*. The winding 11 of primary and secondary coils of a second phase, surrounds the winding leg *b*. The winding of the third phase, also of primary and secondary coils, comprises two groups of coils 12 and 13; each of these groups comprises substantially half the total winding of the third phase and the group 12 surrounds the winding leg *c* while the group 13 surrounds the winding leg *d*. The primary and secondary coils of the individual groups, are shown interleaved and intermixed. The cross areas of the winding legs *a* and *b* are substantially equal; the cross areas of the winding legs *c* and *d* are equal to each other but the cross area of each of these legs *c* and *d* is substantially equal to one-half the cross area of the winding leg *a* (and also of winding leg *b*). These equalities and differences of cross areas are indicated in the drawing by the relative widths of the legs *a*, *b*, *c*, and *d*. All the legs and yokes are assumed to be of equal thickness. The cross area of each yoke and outer leg may be equal to the cross area of each of the winding legs *c* and *d*.

The windings of the three phases are so connected that when the current in any winding is in the positive direction, the magnetomotive force thereof tends to cause a flux to flow in the winding leg or legs of that winding, in the same direction with respect to the center of the core as the magnetomotive force of any other winding tends to cause flux in its winding leg or legs when the current in that other winding is in the positive direction. That is: presuming that the magnetomotive force of the winding 10 tends to cause flux in the direction of the arrow 16 in the leg *a* when the current in the winding 10 is in that direction which is chosen as positive, then when the current in the winding 11 is in the positive direction its magnetomotive force tends to cause flux in the leg *b* in the direction of the arrow 17; and also when the current in the winding 12—13 is in the positive direction, the flux resulting from the magnetomotive force of

this winding alone is in the direction of the arrow 18 in the leg *c* and in the direction of the arrow 19 in the leg *d*. These arrows, it will be observed, point in the direction of the center 20 of the core. It is, of course, not necessary that the flux of each winding be toward the center of the core when the current in that winding is in the positive direction; the flux may be in exactly the opposite direction under the condition of positive direction of current, but if such is the case with respect to any one winding, it must be the same with respect to each of the other two windings if the greatest economy of material is to be secured; if the windings are otherwise connected more material must be used in the construction of the core.

A three-phase induction apparatus such as I have described so far, is economic in material and exhibits a saving in the labor required in its construction. Furthermore, it will be observed that the windings of the three phases are physically quite separate and as little bound together mechanically by the core as may be; that is, each winding may be removed from the core without disturbing any other winding if the two adjacent yokes or two adjacent outer legs (as the case may be) are removed. Sometimes one winding of a polyphase apparatus is damaged without any injury developing in the other two, and for this reason it is advantageous to be able to remove the damaged winding without disturbing the other windings and with the least disturbance of the core possible.

Particularly in order to allow each winding to be readily removed, as well as for economy in material coupled with efficiency in operation and for a saving in the labor required in its construction, I prefer to use the rectangular sections and arrangements of rectangular sections shown in Figs. 2 to 7, in building up the core of Fig. 1.

I contemplate, however, that the core construction of these Figs. 2 to 7 may find a field of usefulness in other than three-phase induction apparatus. Following the preferred construction of induction apparatus cores, the core is made up of laminations of thin layers of the magnetic material, iron or steel. Each lamination or layer of the preferred form of my core comprises a number of rectangular sections as shown in Figs. 2 to 7, the sections in each lamination abutting against each other. In order to break joints, that is, to prevent the occurrence of one joint exactly against or closely adjacent another joint throughout the whole thickness of the core, I provide two sets of laminations, the laminations of the different sets being made up of different arrangements of the same sizes of rectangular sections and the laminations of the different sets being more or less intermixed. Breaking joints

provides a structure having better magnetic operation and greater mechanical strength. The laminations of the different sets may be intermixed in various arrangements, but generally it will be found better to intermix the two laminations in groups of one or two, first one or two laminations of one set, then one or two laminations of the second set, again one or two laminations of the first set, and one or two laminations of the second set, and so on, building up the core to the desired thickness with the laminations of the two sets disposed and intermixed in such an order. The sections are all of equal widths and, of course, of equal thicknesses. They are, however, of different lengths as appears. The reference characters indicating the different legs and yokes of the complete core previously described, appear in their respective places on Figs. 2 to 7 in order to show the distribution of the rectangular sections in the completed core. The distribution of the rectangular sections in one of the laminations of what may be called the first set, is shown in Fig. 2. In this lamination two sections 25 and 26, placed edge to edge, extend from the inner edges of yokes *e* and *f* through both legs *a* and *b* to the inner edges of yokes *g* and *h*. A section 27 extends from one edge of the legs *a* and *b* to the outer edge of the outer legs *i* and *j*. A similar section 28 extends from the opposite edge of the legs *a* and *b* to the outer edge of the outer legs *l* and *k*. These sections 27 and 28 comprise, respectively, parts of the legs *d* and *c*. A section 29 extends from the inner edge of the outer leg *k* through both yokes *e* and *f* to the inner edge of the outer leg *j*, and section 30, similar to section 29, extends from the inner edge of leg *l* through both yokes *g* and *h* to the inner edge of the outer leg *i*. Section 31 extends from an edge on the inner leg *c* through the adjacent outer leg *k* to the outer edge of the adjacent yoke *e*, and other similar sections 32, 33 and 34 extend from an edge of the inner leg *c* or inner leg *d* through the respective adjacent outer leg *l*, *j* or *i* to the outer edge of the respective adjacent yoke *g*, *f* or *h*. A lamination of the second set of laminations is shown in Fig. 3. In this lamination the rectangular sections are disposed as follows:—Two sections 38 and 39 placed edge to edge extend from the outer edge of the yokes *e* and *f* through the leg *a* to the edge of the adjacent legs *c* and *d*. Two similar sections 40 and 41 also placed edge to edge extend from the opposite edge of legs *c* and *d* through leg *b* to the outer edge of yokes *g* and *h*. A section 42 extends from the inner edge of the outer legs *k* and *l* through both legs *c* and *d* to the inner edge of the outer legs *j* and *i*. A section 43 extends from the inner edge of the yoke *e* through legs *k* and *l* to the inner edge of yoke *g*, and a similar

section 44 likewise extends from the inner edge of the yoke *f* through both yokes *j* and *i* to the inner edge of the yoke *h*. A section 45 extends from one edge of the inner leg *a* through the adjacent yoke *i* to the outer edge of the adjacent outer leg *h*, and similar sections 46, 47 and 48 extend from an edge of the inner leg *a* or the inner leg *b* through the respective adjacent yoke *f*, *g*, or *h* to the outer edge of the respective adjacent outer leg *j*, *l* or *i*. As before indicated, the complete core comprises a number of the laminations of Figs. 2 and 3 more or less intermixed. It will be seen, that from a core of this construction it is possible to remove a winding about the leg *a* by merely removing the rectangular lamination sections forming the yokes *e* and *f*; similarly to remove a winding from the leg *b*, it is only necessary to remove the sections forming the yokes *g* and *h*, and to remove the windings from the legs *c* and *d*, it is necessary to remove only the lamination sections forming the legs *k* and *l* and *j* and *i*, respectively.

A lamination adapted to provide a central air passage through the core is shown in Fig. 4. In this lamination the rectangular sections are disposed as follows:—

The sections 55 and 56 are placed side by side, but not edge to edge, thus leaving a space between the right hand and left hand portion of the lamination which in the assembled laminations becomes the central air passage in the core. These sections extend, as before, from inner edges of yokes *e* and *f* through both legs *a* and *b*, each of which now has a right and left hand half, to the inner edges of yokes *g* and *h*. A section 57 extends from the outer edge of section 56 to the outer edge of legs *i* and *j*; while a section 58 similarly extends from section 55 to the outer edge of legs *l* and *k*. A section 59 completes the yoke *e* and a corresponding one 59' completes yoke *f*; while similar sections 60 and 60' complete yokes *g* and *h* respectively. Section 61 extends from an edge on the inner leg *c* through the adjacent outer leg *k* to the outer edge of the adjacent yoke *e* while other similar sections 62, 63, and 64 extend from an edge of the legs *c* or *d* through their respective adjacent legs, *l*, *j* and *i* to the outer edge of the yokes *g*, *f* and *h*. A lamination of a second or alternate set to go with the one just described may have their inner and outer sections 55 and 56 interchanged with those of sections 61, 62, 63 and 64 in the manner shown in Fig. 3 as compared with those in Fig. 2 in order to break joints, or the whole lamination may be made in the manner shown in Fig. 5 where the right and left portions are interchanged in the alternate layers of the assembled laminations to break joints.

In Fig. 5 the section 68 is laid by the side of sections 69 and 70, but spaced apart so

as to permit the formation of a central air passage. Here the section 68 extends from the inner edge of yoke *e* through leg *c* to the inner edge of yoke *g*; while section 69 extends from one edge of leg *d* to the outer edge of yoke *f*, section 70 similarly extending from an edge of leg *d* to the outer edge of yoke *h*. In a similar manner section 71 is placed to form legs *i* and *j* and extends from an inner edge of yoke *f* to an inner edge of yoke *h*. Sections 72 and 73 are placed to form legs *k* and *l* respectively, and extend from an edge of leg *c* to an outer edge of yokes *e* and *g* respectively. The legs *c* and *d* are formed respectively by the sections 74 and 74' while sections 75, 76, 77 and 78 are placed so as to extend from edges of the adjacent leg members to complete the yokes *e*, *f*, *g* and *h* respectively.

In Fig. 6 a lamination in contour similar to that shown in Fig. 4, is shown as assembled from L-shaped sections instead of from rectangular sections. Here L-shaped sections 80 and 81 are placed side by side, but spaced apart, and abut respectively against rectangular sections 82 and 83 which have been similarly placed but spaced apart, in order that the four sections may form the legs *a* and *b* and provide a central air passage. The bases of the L-shaped sections 80 and 81 are arranged to extend oppositely away from each other to form yokes *e* and *f*. An L-section 84 is placed to have its base extending away from the outer edge of legs *a* and *b* and thus form leg *c*; the leg of the L-section 84 extends upwardly to the inner edge of yoke *e*, forming leg *k*.

Another L-section 85 is placed to have its base abut the lower outer edge of leg *b*, extending in a direction to form yoke *g*; the leg portion of the L-section extends up to meet an edge of leg *c*, thus forming leg *l* of the lamination.

In a similar manner the L-section 86 is placed to have its base abut against an outer edge of legs *a* and *b* to form legs *d* and *j* of the lamination, and the L-section 87 to form leg *i* and yoke *h*. The lamination alternating with the one described to break joints would have the right and left hand portions reversed. But another form of lamination is shown in Fig. 7 assembled from L-sections in which joints may be broken merely by interchanging right and left hand portions.

Here in Fig. 7 the L-sections 90 and 91 are placed side by side and spaced apart but with bases alternately at top and bottom and extending in opposite directions. The L-sections 90 and 91 thus form leg *a* while their base portions form respectively yoke *e* and leg *d*. Abutting against the L-sections 90 and 91 respectively are the rectangular section 92 and the L-section 93. These sections are placed side by side and

spaced apart, the base portion of L-section 93 extending away from the leg *b* (formed by the juxtaposition of these sections) so as to form yoke *h*. An L-section 94 is placed to extend from an inner edge of yoke *e* and from leg *k* and thence from its knee to extend to about an outer edge of leg *b* to form leg *c*. In a similar manner L-section 95 is placed to form leg *l* and yoke *g*. So also L-section 96 and rectangular section 97 are placed to complete the yoke *f* together with leg *j* and the leg *i* respectively.

While in preparing the core for the three-phase induction apparatus primarily described, I prefer to use an arrangement of laminations shown in Figs. 2 to 7, intermixed in the manner afore described; yet it will be understood that this three-phase apparatus does not necessarily have a core thus constructed.

Also it will be understood that while the embodiment of my invention hereinbefore described is the best embodiment of which I am now aware, this embodiment is merely illustrative of my invention and my invention is not limited thereto but is set forth in the following claims.

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

1. Three-phase induction apparatus comprising a core having four winding legs at right angles to each other and external members completing the magnetic circuits by joining the adjacent outer ends of said winding legs, a winding of one phase about one of said winding legs, a winding of a second phase about the opposite winding leg, and a part of the winding of the third phase about each of the two winding legs which are at right angles to the first mentioned two winding legs.

2. Three-phase induction apparatus comprising a core having four winding legs at right angles to each other and external members completing the magnetic circuits by joining the adjacent outer ends of said winding legs, a winding of one phase about one of said winding legs, a winding of a second phase about the opposite winding leg, and a part of the winding of the third phase about each of the two winding legs which are at right angles to the first mentioned two winding legs, said windings being so connected that when the current in any winding is in the positive direction the flux thereof traverses the winding leg or legs of that winding in the same direction with respect to the center of said core as the flux of any other winding traverses its winding leg or legs when the current in that other winding is in the positive direction.

3. Three-phase induction apparatus comprising a core having two winding legs of equal cross areas joined together and extending in opposite directions, two other winding legs each of approximately one half the cross area of each of the first mentioned two winding legs and joined to and extending in opposite directions from the juncture of the same and at right angles thereto, and yokes and outer legs completing the magnetic circuits, a winding of one phase about one of the first mentioned two winding legs, a winding of a second phase about the other of said first mentioned two winding legs, and approximately half of the winding of the third phase about each of the winding legs at right angles to the first mentioned two winding legs, said windings being so connected that when the current in any winding is in the positive direction the flux thereof traverses the winding leg or legs of that winding in the same direction with respect to the center of said core as the flux of any other winding traverses its winding leg or legs when the current in that other winding is in the positive direction.

4. A laminated core for induction apparatus, comprising four inner legs, *a*, *b*, *c* and *d*, joined to each other and forming right angles at their inner ends, yokes *e*, *f*, *g* and *h*, and outer legs *i*, *j*, *k* and *l*, joining the outer ends of said inner legs to complete the magnetic circuits therethrough, the laminations being of any mixed sets of rectangular sections of equal widths, the inner legs *a—b* of one set of laminations comprising two sections placed side by side and abutting at their ends against the inner sides of single sections forming the yokes *e—f* and *g—h* respectively and the inner legs *c—d* of the same set of laminations formed of sections abutting at one end against one side of one of the sections forming the legs *a* and *b*, and their other ends extending between the ends of the outer legs *i—j* and *k—l* respectively and the inner legs *c* and *d* of the other set of laminations comprising a single section abutting at its ends against the inside edges of single sections forming the outer legs *i—j* and *k—l* respectively, the inner legs *a* and *b* of the same set of laminations each comprising two sections placed side by side and abutting at one end against one side of the section forming the inner legs *c—d* and at their other ends extending between the ends of the yokes *e—f* and *g—h*, respectively.

In witness whereof, I have hereunto set my hand this 22 day of August, 1919.

JOHN J. FRANK.