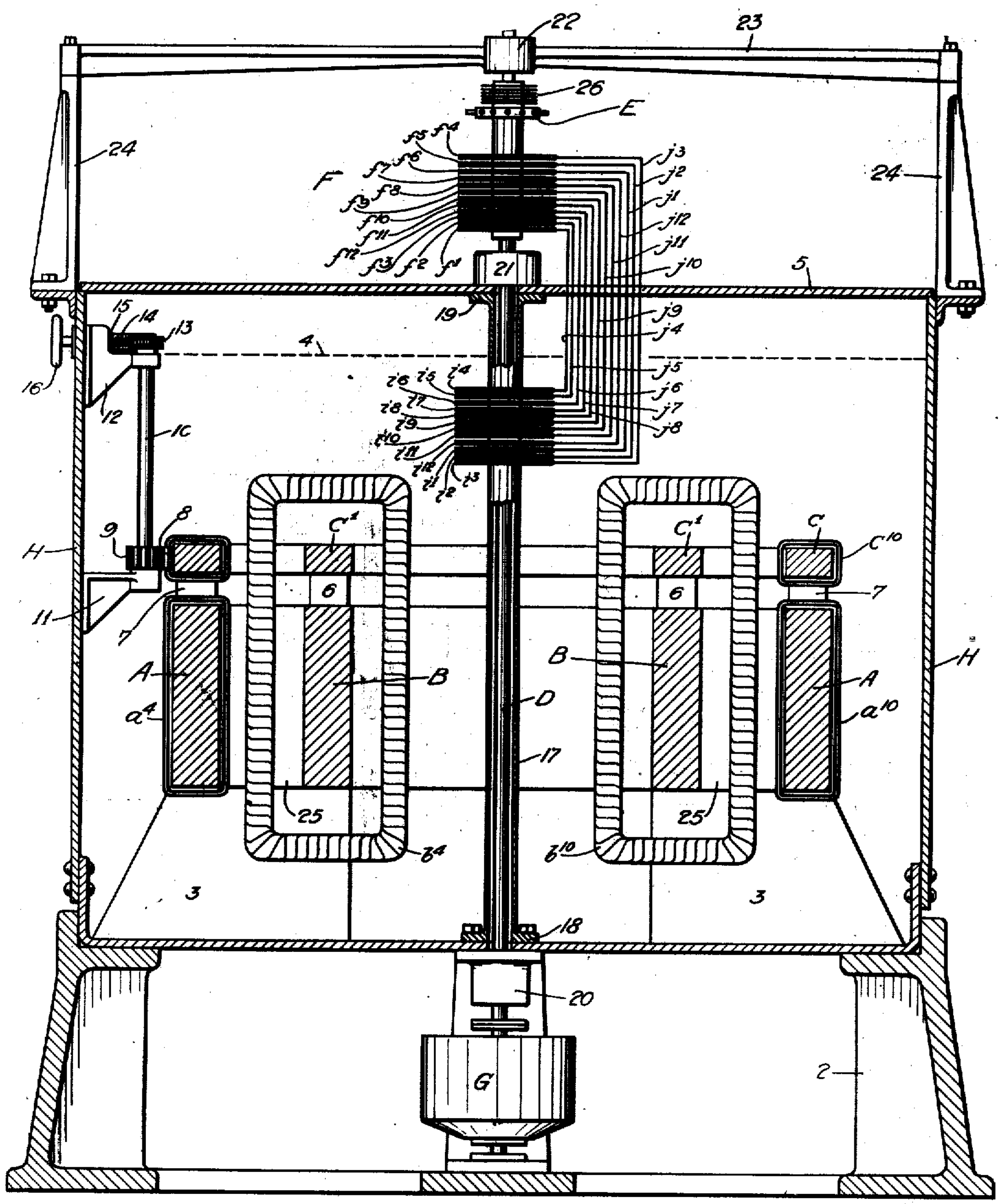
A. F. NESBIT.
DIRECT CURRENT TRANSFORMER.
APPLICATION FILED MAR. 9, 1921.

1,421,538. **Patented July 4, 1922.**

5 SHEETS—SHEET 1.

FIG. 1.



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5 SHEETS—SHEET 2.

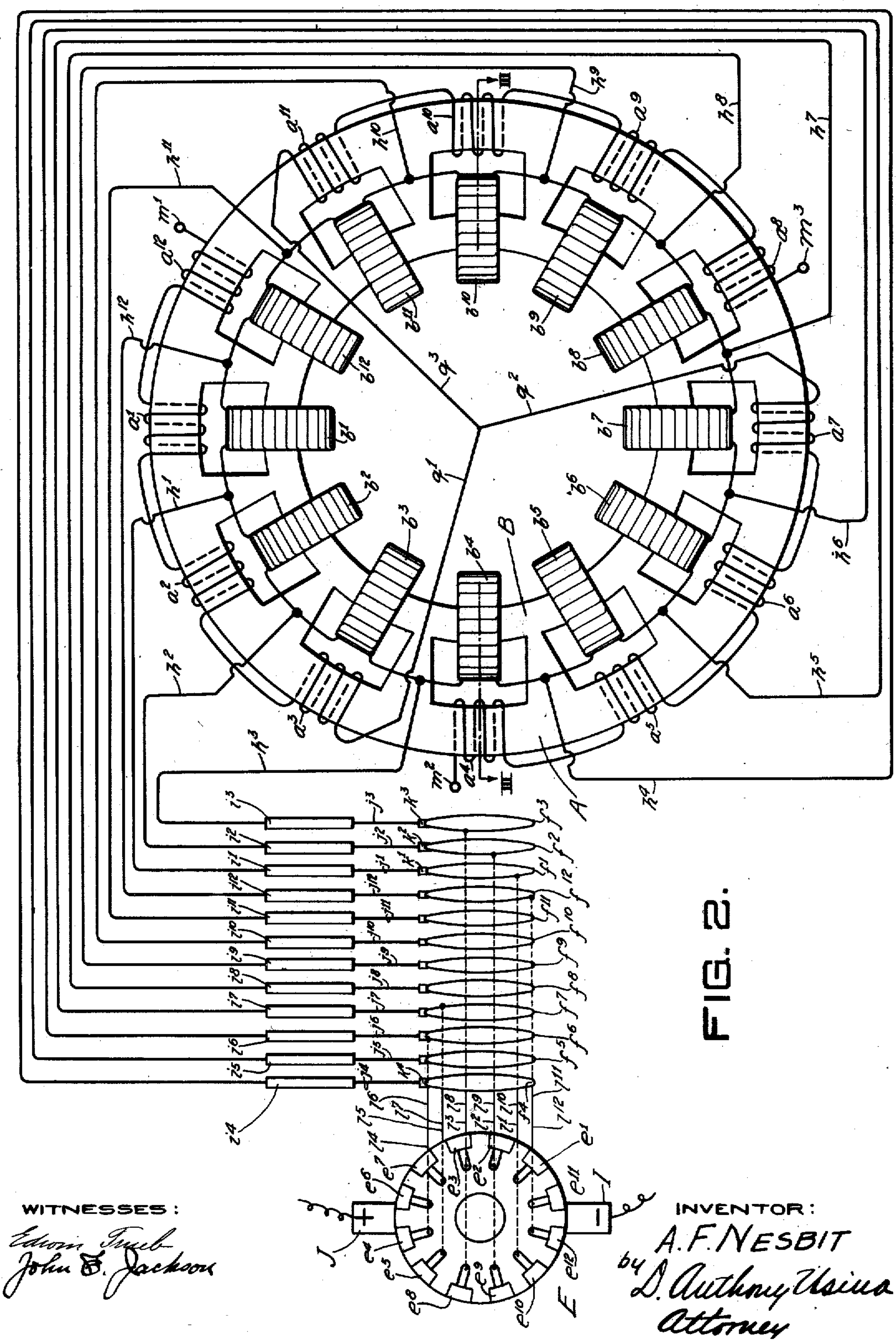

FIG. 2.

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5 SHEETS—SHEET 3.

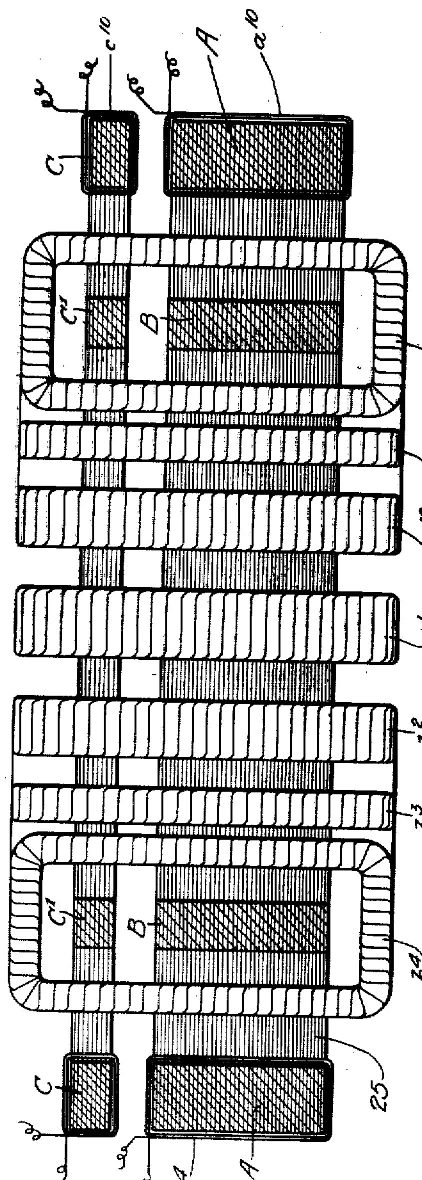

FIG. 3

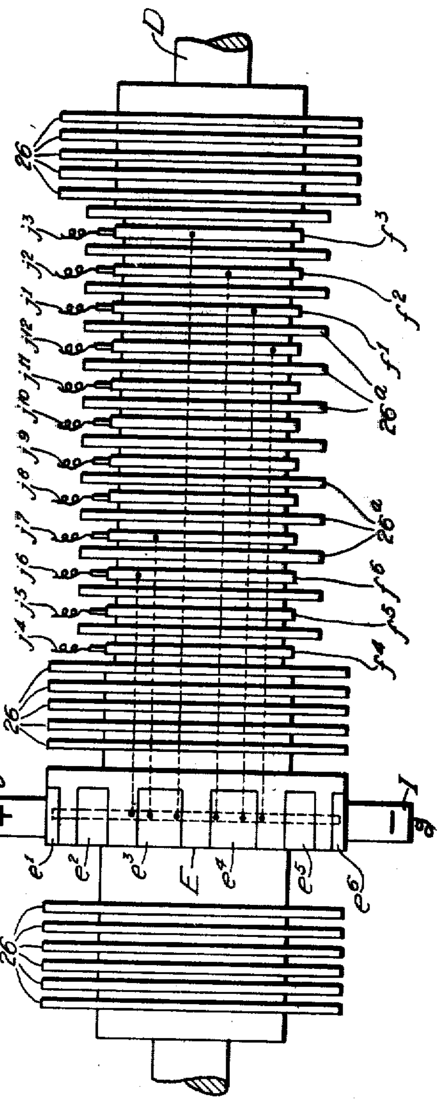

FIG. 5.

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5 SHEETS—SHEET 4.

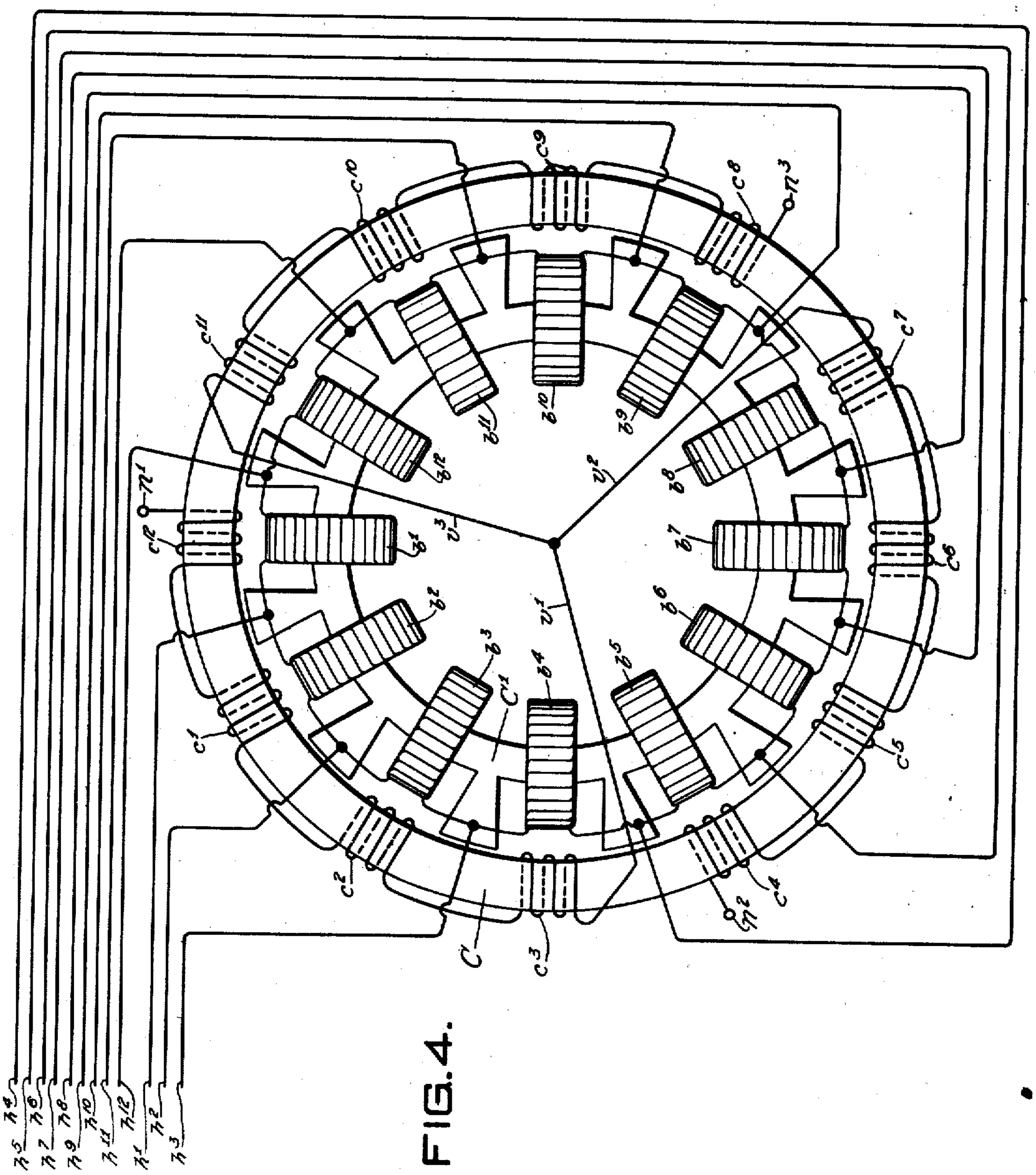

FIG. 4.

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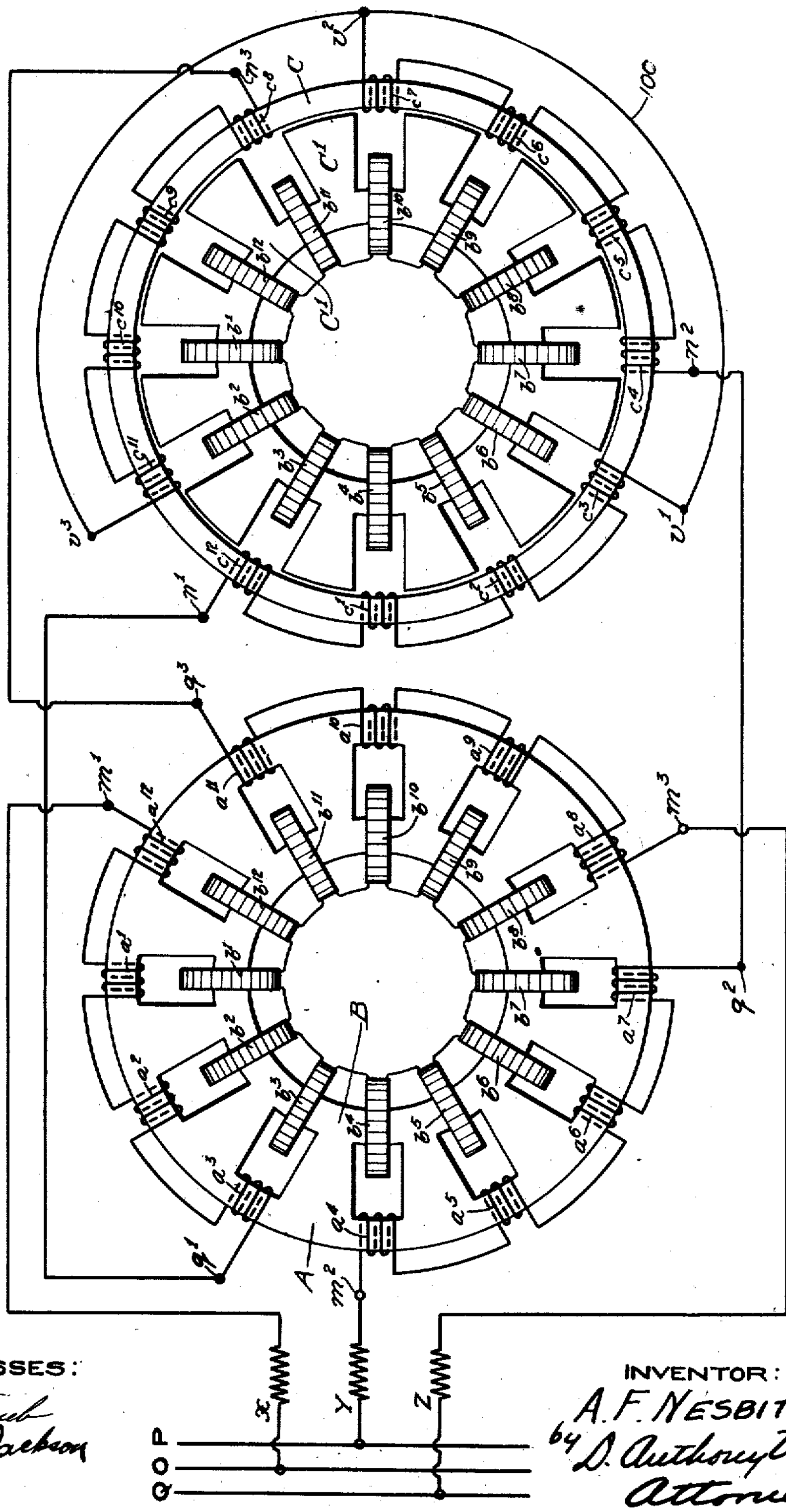
5 SHEETS—SHEET 5.

FIG. 6.



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UNITED STATES PATENT OFFICE.

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DIRECT-CURRENT TRANSFORMER.

1,421,538. Specification of Letters Patent. Patented July 4, 1922.

Application filed March 9, 1921. Serial No. 450,988.

To all whom it may concern:

Be it known that I, ARTHUR F. NESBIT, a citizen of the United States, and resident of Wilkinsburg, in the county of Allegheny and State of Pennsylvania, have invented certain new and useful Improvements in Direct-Current Transformers, of which the following is a specification.

My invention relates to direct current transformers of the class described and claimed in my co-pending application, Serial Number 164,430, filed April 25, 1917, Patent No. 1,371,994, March 15, 1921, and relates particularly to means for securing the same phase of currents in the primary coils of both the main and commutating fields.

The principal object of this invention is to provide means for securing exact phase coincidence of currents in the main and commutating primary field coils of my direct current transformer by connecting said coils in series with each other.

Referring now to the drawings, forming part of this specification, Figure 1 is an elevation, partly in section and partly diagrammatic, showing a high potential, direct current, vertical transformer, (i. e. a transformer having an axially vertical commutator shaft) constructed and arranged in accordance with my invention.

Figure 2 is a diagrammatic plan, on a somewhat larger scale (with the commutating field core and its windings omitted for the sake of clearness), showing a preferred grouping of the series of high voltage coils on the locked rotor, and showing the connections between the rotor coils and the commutator, on the commutator shaft in the particular construction illustrated in Figure 1.

Figure 3 is a sectional elevation of the cores and the windings or coils of the stator and rotor cores (shown in the preceding figures,) and the commutating field cores the section being taken on the line III—III of Figure 2.

Figure 4 is a diagrammatic plan, similar to that of Figure 2, showing the commutating field cores and the windings and connections to the windings on the axially adjustable primary commutating field core.

Figure 5 is a plan showing details in the construction and arrangement of the slip rings and commutator segments and leads therefor as mounted on the commutator shaft and shown diagrammatically in Figure 2.

Figure 6 is a diagrammatic view of the primary coils of the main and commutating fields of the transformer showing the series circuit connections used to secure the same phase of currents in the two sets of coils.

In the accompanying specification, due to the fact that the apparatus to be described is similar in structure to an induction motor, the terms "stator and rotor cores and coils," respectively, are employed to designate the parts of the apparatus, which function similar to the phenomena present in the operation of an induction motor. However, since the part of this apparatus corresponding to the rotor core and coil of an induction motor is at all times locked or stationary, the term rotor is qualified by referring to said part as a "locked rotor."

In the accompanying drawings the letter A designates the primary or stator core and B the secondary or locked rotor core, of the annular, integrated structure forming these cores. By integrated, as used herein, is meant a laminated structure having each lamina transversely divided into a series of segments and each segment forming part of the core A and also part of the core B. When constructed as shown, the cores have windings thereon forming twelve primary or stator coils a^1, a^2, a^3, a^4, a^5, a^6, a^7, a^8, a^9, a^{10}, a^{11}, and a^{12}, and equal number of secondary or locked rotor coils b^1, b^2, b^3, b^4, b^5, b^6, b^7, b^8, b^9, b^{10}, b^{11}, and b^{12}.

Mounted above and in axial alinement with the stator and rotor cores are the commutating field cores C and C^1 of my improved transformer. The angularly adjustable primary field core C has windings thereon forming its coils c^1, c^2, c^3, c^4, c^5, c^6, c^7, c^8, c^9, c^{10}, c^{11}, and c^{12}. The stationary secondary commutating field core C^1 is embraced or encircled by the windings forming the coils b^1, b^2, b^3, etc., of the locked rotor B (as is shown in Figures 1, 2 and 3).

Extending vertically through the axially central and axially alined openings in the cores B and C is a rotary commutator shaft D and positioned on this shaft adjacent to its upper end, is a segmental commutating group or commutator E (Figures 2 and 5) and co-operating group of slip rings F, to which the segments of the commutator E are permanently connected electrically. The lower end of the shaft D is connected to the armature shaft of a synchronous motor G by which the shaft D is rotated. This motor, as shown, is positioned below the oil tank or container H in which the stator A, locked rotor B, and commutating field cores C and C^1 are positioned so as to be submerged in the oil. It will be obvious, however, that the motor G may be supported above the tank H and be connected to the opposite end of the shaft D and also that the shaft D and its driving motor G may be located at a distance from the cores and coils of my improved apparatus.

The tank H is secured on a support 2 which is fixed on a suitable foundation and the cores A, B, are supported within the tank on a series of radial supports 3. The tank, which is cylindrical in cross section, is filled with oil to about the level indicated by the broken line 4, to keep the stator A and rotor B immersed in the oil and provide for effective insulation of the stator and rotor, and the tank has a tight cover or lid 5 on its upper end.

Suitable supports 6 are provided above or on top of the locked rotor core B upon which the stationary or secondary core C^1 of the commutating field core is positioned, and similar supports 7 above or on top of the stationary stator core A provide means for supporting the angularly adjustable, axially movable primary commutating field core C and series of windings forming its coils c^1, c^2, c^3, etc.

The primary commutating field core C is arranged to turn angularly relative to the stator and locked rotor cores A and B and the coils a^1, a^2, etc., and b^1, b^2, etc., thereon, this field core C turning about the vertical axis of the stator and locked rotor when being adjusted relative thereto and a suitable manually operated adjusting mechanism being provided for turning the commutating field core C and for locking the core C in adjusted position (see Figure 1).

As shown, the adjusting mechanism comprises a segmental gear or curved rack 8 secured on the periphery of the core C and having teeth in mesh with those of the pinion 9 on one end of the vertical shaft 10. The shaft is rotatably secured in the bracket bearings 11 and 12, which are fastened to the vertical wall of the tank H, and extends upwardly to or above the oil level 4 in the tank. The upper end of the shaft 10 is provided with a worm wheel 13 which meshes with the worm 14 on one end of the horizontal shaft 15, this shaft also being rotatably mounted in the upper bracket bearing 12. The shaft 15 extends through a stuffing box and gland on the side wall of the tank H and is provided on its outer end with a hand wheel 16 for turning the shafts 10 and 15 to adjust the primary commutating field core C and its coils c angularly with respect to the stator A and rotor B and coils a and b therefor. As the adjustable commutating field core must be held in its adjusted positions, the worm wheel 13 and worm 14 conveniently serve as a lock therefor in addition to transmitting motion from the shaft 15 to the shaft 10.

The rotary commutator shaft D, which is shown centered on the vertical axis of the annulus forming the cores A and B for the stator and locked rotor, (and the axis of the tank H), extends through a tube 17 in the tank H and is provided, adjacent to its upper end, with the commutator or segmental commutator group E and co-operating group F of twelve slip rings, f^1, f^2, f^3, f^4, f^5, f^6, f^7, f^8, f^9, f^{10}, f^{11}, and f^{12}. The tube 17 is fastened, by a flange 18 on its lower end to the bottom of the tank H to form an oil tight joint therebetween and a flange 19 on its upper end is secured to the cover or lid 5 of the tank to rigidly fasten the tube in upright position within the tank. The vertical shaft D is rotatably mounted in bearings 20, 21, which are secured to the ends of the tank H, and a third bearing 22, on the spider 23 is provided for the upper end of the shaft D. The spider 23 is secured in position on the upper ends of vertical posts 24 which are fastened to the upper end of the tank D.

As shown, (Figures 1, 2, and 3) the laminated, annular structure forming the integrated cores A and B is provided with a series of twelve rectangular or substantially rectangular openings or gaps 25, through which extend the windings forming the coils a^1, a^2, a^3, etc., of the stator A and coils b^1, b^2, b^3, etc., of the locked rotor B, when these coils are assembled in operative position on the cores. To facilitate assembling the parts forming the integrated or unitary cores A and B, each lamina should be slitted and in building up the laminated structure the slits in the laminae should be staggered to form overlapping joints. Such expedient being old and well known in making laminated cores, need not be further described.

The primary or stator circuit as shown, has a series of twelve polyphase windings a^1, a^2, etc., these coils preferably being connected in Y or, in star and the groups of coils having terminals m^1, m^2, and m^3, (see Figure 2). The secondary or locked rotor circuit has a series of twelve polyphase windings or coils b^1, b^2, b^3, b^4, b^5, b^6, b^7, b^8, b^9, b^{10}, b^{11}, and b^{12}, which are connected in closed series as in a closed coil Gramme ring armature, the series of coil b^1, b^2, etc., being properly insulated against the potential to be carried thereby.

Positioned immediately above the primary or stator core A and its coils a^1, a^2, etc., so as to be adjustable angularly relative to the coils on the core A, is the primary commutating field core C and its series of twelve windings or coils c^1, c^2, c^3, c^4, c^5, c^6, c^7, c^8, c^9, c^{10}, c^{11}, and c^{12}, which are also connected in Y or in star, and the groups of coils having terminals n^1, n^2, n^3 (Figure 4); and immediately above the secondary or locked rotor core B is the secondary or stationary core C^1, of the commutating field core, this core C^1, being embraced or encircled by the windings forming the coils b^1, b^2, etc., of the locked rotor core B (Figures 1, 2, and 4).

The terminals n^1, n^2, and n^3 of the three groups of coils forming the primary commutating circuit, however, are not located directly above the similar points m^1, m^2, and m^3, on the main primary circuit, but are displaced forward or backward with reference to them. This will represent a maximum possible magnetic displacement of approximately 90 degrees The magnetic flux produced by the windings c^1, c^2, c^3, etc., will lag or lead according to the extent of adjustment with reference to the main primary magnetic flux.

The terminals of each coil of the electrically adjacent locked rotor coils b^1 and b^2, b^2 and b^3, b^3 and b^4, b^4 and b^5, b^5 and b^6, b^6 and b^7, b^7 and b^8, b^8 and b^9, b^9 and b^{10}, b^{10} and b^{11}, b^{11} and b^{12}, b^{12} and b^1 are connected together and have a common lead h^1, h^2, h^3, h^4, h^5, h^6, h^7, h^8, h^9, h^{10}, h^{11}, or h^{12} and these leads, as shown are connected each to its individual ring i^1, i^2, i^3, i^4, i^5, i^6, i^7, i^8, i^9, i^{10}, i^{11}, and i^{12}. The group of bus rings i^1, i^2, etc., which encircles the shaft D and tube 17, is located within the tank H so as to be immersed in the oil in this tank. Each of the rings i^1, i^2, etc., has a lead j^1, j^2, j^3, j^4, j^5, j^6, j^7, j^8, j^9, j^{10}, j^{11}, and j^{12}, which extends upwardly through an insulated opening in the tank cover or lid 5 and is connected by a carbon brush k^1, k^2, k^3, k^4, k^5, k^6, k^7, k^8, k^9, k^{10}, k^{11}, and k^{12}, to one of the slip rings f^1, f^2, f^3, etc., in the group F of slip rings fastened on and rotating with the commutator shaft D.

Obviously the rings i and leads j may be omitted, in such case the leads h extending to the brushes k for the slip rings f.

The slip rings f^1, f^2, etc., are permanently connected electrically by leads l^1, l^2, l^3, etc., one to each of the commutator segments e^1, e^2, e^3, etc., forming the commutator E on the rotary commutator shaft D adjacent to the slip rings. (See Figure 5).

The commutator segments e^1, e^2, e^3, etc., are insulated from the shaft D and from each other in any of the various known ways and this insulation may conveniently be utilized to support and insulate the leads l^1, l^2, etc. The necessary number of leakage rings 26 will be provided at the ends of the group F of slip rings and on each side of the commutator F, and preferably a leakage ring 26^a will be supplied on the commutator shaft D between the adjacent slip rings f^1, f^2, etc., as shown in Figure 5.

By splitting up the primary windings into a plurality or groups of coils, instead of one group for each phase as shown and described in connection with the apparatus of Figures 1, 2, and 3, a multiplicity of rotary fields will be obtained, instead of a single two pole rotary field, this having the effect of decreasing the secondary voltage and increasing the current carrying capacity of the locked rotor or secondary circuit, by permitting the parallel grouping of the secondary coils.

The brush I on the commutator E is connected to the negative lead K and the brush J for the positive terminal is connected to the lead L, these leads K, L, extending to the apparatus utilizing the high potential unidirectional current generated by my improved apparatus.

The windings forming the primary or stator coils a^1, a^2, etc., are connected in three groups of four coils each, the coils a^{12}, a^1, a^2, and a^3, forming one group, the coils a^4, a^5, a^6, and a^7, the second group, and the other coils a^8, a^9, a^{10}, and a^{11}, the third group. The coils of each group are connected in series, the leads q^1, q^2, q^3, from one terminal of the coils a^3, a^7, and a^{11}, at one end of each group being connected in star, and one terminal of the coils a^4, a^8, and a^{12}, at the other end of each group being connected by a lead m^1, m^2, and m^3, to a conductor leading to the source of alternating current.

The terminals n^1, n^2, and n^3, for the three groups of coils c^{12}, c^1, c^2, c^3,—c^4, c^5, c^6, c^7,—c^8, c^9, c^{10}, c^{11}, on the commutating field core C are connected in the same way as the stator coils a^1, a^2, etc., to the source of alternating current used in operating my improved transformer and the terminals for the other end of the groups of coils being connected in star by leads v^1, v^2, and v^3. The terminals for the synchronous motor G also are connected to the source of alternating current.

The commutating field serves for commutating purposes only and contributes no additive effect toward securing higher values of commutated direct-current voltages. The commutating and main fields in this transformer have the proper angular disposition in space, as shown in Figure 6, and the proper relative field strength, so that a forward or backward lead of the commutating field does not alter the angular width of the neutral zone.

For convenience and simplicity in operation it is preferred to connect each set of coils of one phase of the commutating field in series with a proper corresponding set of coils of one phase of the primary or stator winding the core A. By this series-star connection of the commutating and primary or stator coils an exact phase coincidence of the currents in these same coils may be brought about for all current values with the result that the proper angular lead, either forward or backward, of the commutating field, can readily be secured.

In Figure 6 I have shown diagrammatically the circuit connections which I prefer to use in order to secure the same phase of currents in the primary coils a^1 to a^{12} of the main field of Figure 2, and the primary coils c^1 to c^{12} of the commutating field of my transformer.

The three phases of these two separate and distinct sets of primary coils are shown connected in series-star fashion, so that the circuits may be traced from the three phase current supply lines O, P, and Q, as follows:—Line O through resistance X, terminal m^1 coils a^{12}, a^1, a^2, a^3, lead q^1, terminal n^1, coils c^{12}, c^1, c^2, c^3, and star lead v^1 to star connection 100. Line P through resistance Y, terminal M^2, coils a^4, a^5, a^6, a^7, lead q^2 terminal n^2, coils c^4, c^5, c^6, c^7, and star lead v^2 to star connection 100. Line Q through resistance Z, terminal m^3, coils a^8, a^9, a^{10}, a^{11}, lead q^3, terminal n^3, coils c^8, c^9, c^{10}, c^{11}, and star lead v^3 to star connection 100.

It will thus be seen that each set of coils of one phase of the commutating field is connected in series with a corresponding set of coils of one phase of the primary or stator windings. Therefore an exact phase coincidence of the currents in these same coils is brought about for all current values.

The resistances X, Y, and Z, may be of any well known construction and are adapted to take care of the varying demands for current supplied by the transformer.

It will be understood that I do not wish to be limited to the specific construction shown since various changes in the construction and arrangement of parts may be made without departing from the spirit of my invention as defined in the appended claims.

I claim:—

1. A transformer comprising a main field having integrated primary and secondary cores, a plurality of coils on said primary and secondary cores, a core having a plurality of coils forming a commutating field, said commutating field being angularly adjustable about the axis of said primary and secondary cores, each group of commutating field coils being in series with a corresponding group of the primary or stator coils, a commutator group connected to the coils of said secondary core, and collectors for said commutator group.

2. A transformer comprising a main field having integrated primary and secondary cores, a plurality of coils on said primary and secondary cores, a core having a plurality of coils forming a commutating field, said field being angularly adjustable about the axis of said primary and secondary cores, each group of commutating field coils and each corresponding group of the primary or stator coils being connected in series-star fashion so as to obtain the exact phase coincidence and equal current values in the main and commutating primary field coils.

3. A transformer comprising a main field having integrated primary and secondary cores, a plurality of coils on said primary and secondary cores, a core having a plurality of coils forming a commutating field, said field being angularly adjustable about the axis of said primary and secondary cores, each group of commutating field coils being in series with a corresponding group of the primary or stator coils so as to obtain the exact phase coincidence and equal current values in the main and commutating primary field coils, and the group series of coils being connected in star, a commutator group connected to the group of coils of said secondary core, and collectors for said commutator group.

4. A transformer comprising a main field having integrated primary and secondary cores, a plurality of coils on said primary and secondary cores, a core having a plurality of coils forming a commutating field, said fields being displaced approximately 90 degrees in phase and said commutating field being angularly adjustable about the axis of said primary and secondary cores, each group of commutating field coils being in series with a corresponding group of the primary or stator coils, and the group series of coils being connected in star, a commutator group connected to the group of coils of said secondary core, and collectors for said commutator group.

In testimony whereof I have hereunto set my hand.

ARTHUR F. NESBIT.