A. F. NESBIT.

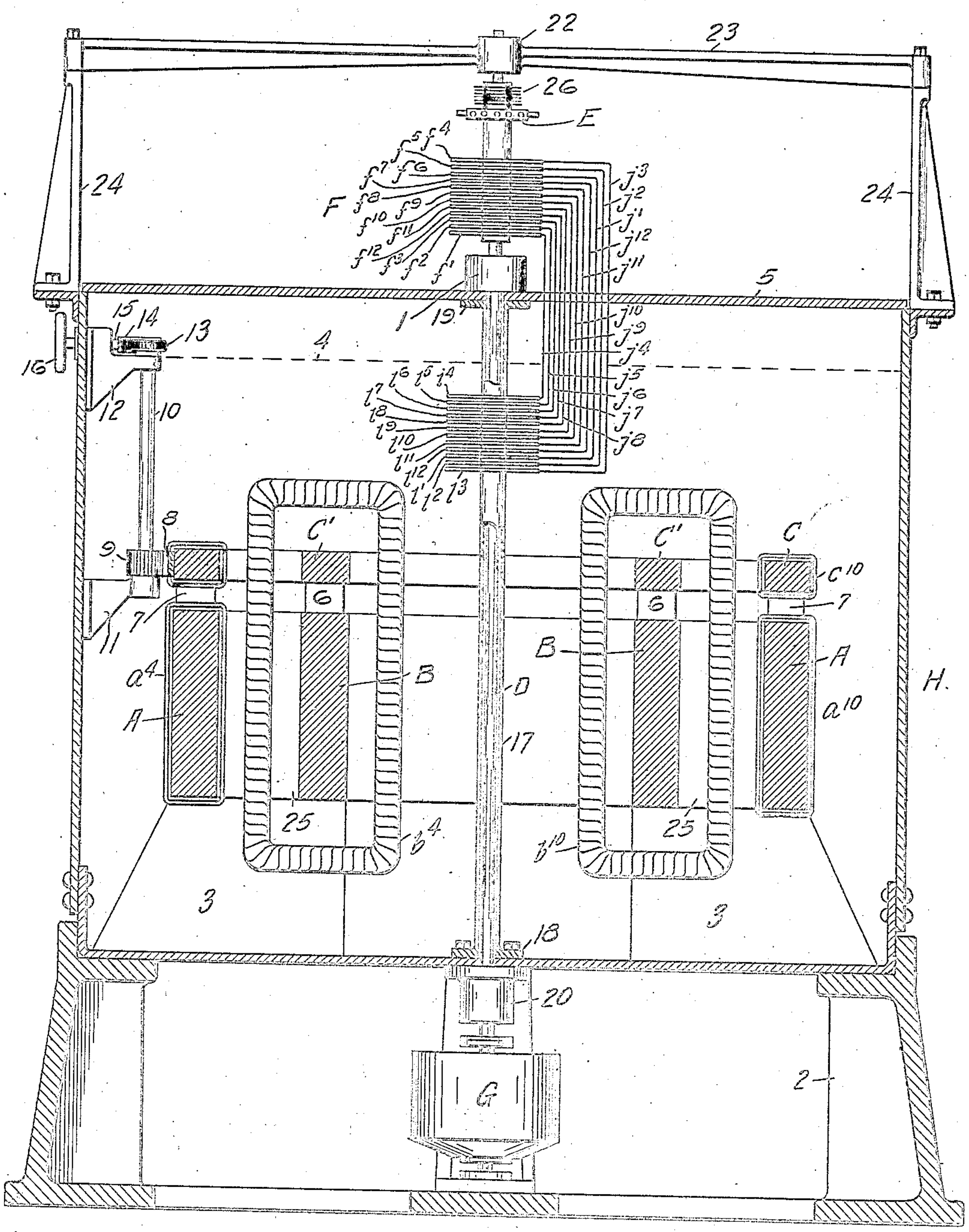
DIRECT CURRENT TRANSFORMER.

APPLICATION FILED APR. 25, 1917.

1,371,994. Patented Mar. 15, 1921.

5 SHEETS—SHEET 1.

FIG. 1



WITNESSES

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5 SHEETS—SHEET 2.

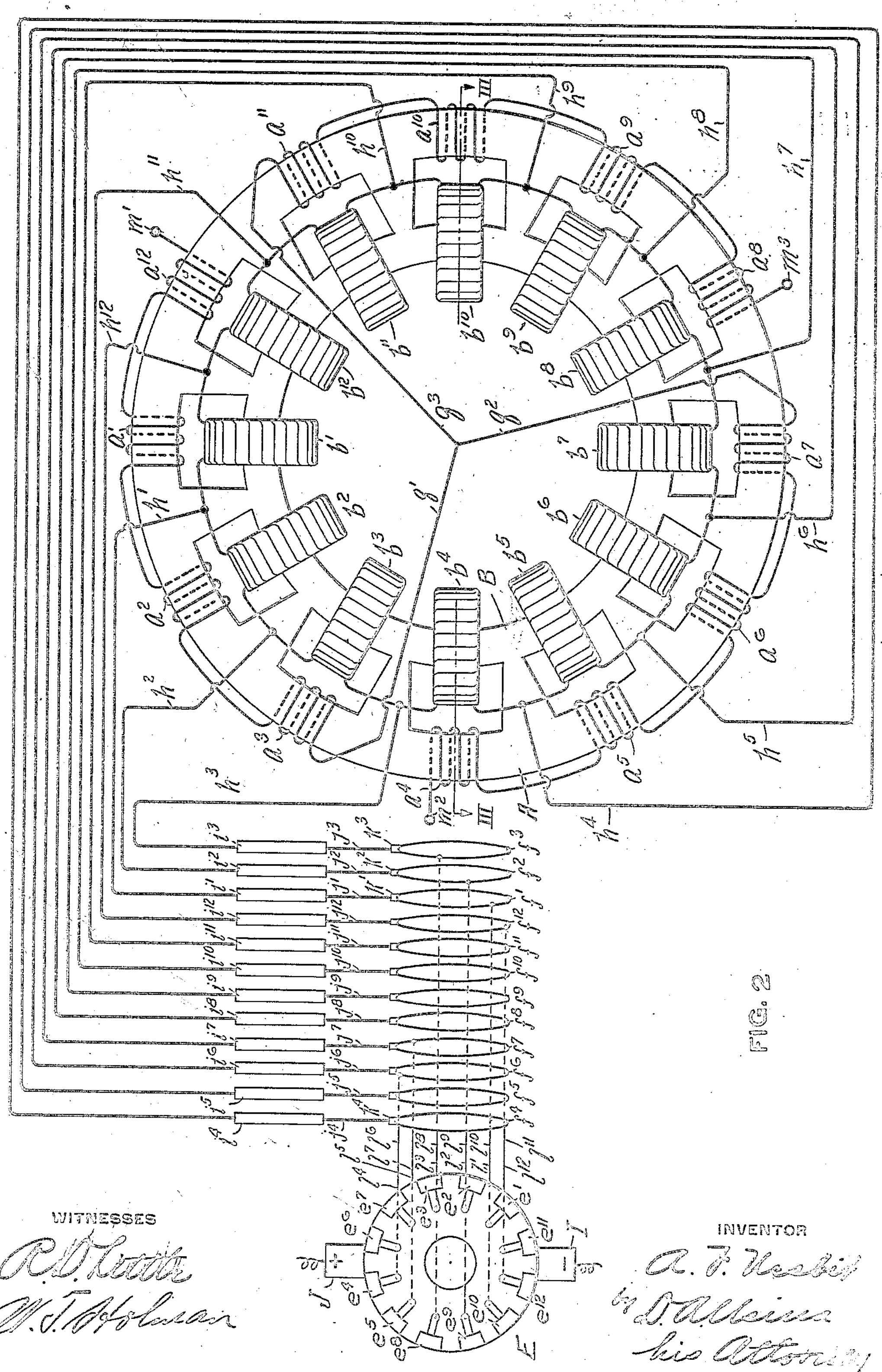

FIG. 2

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5 SHEETS—SHEET 3.

FIG. 3

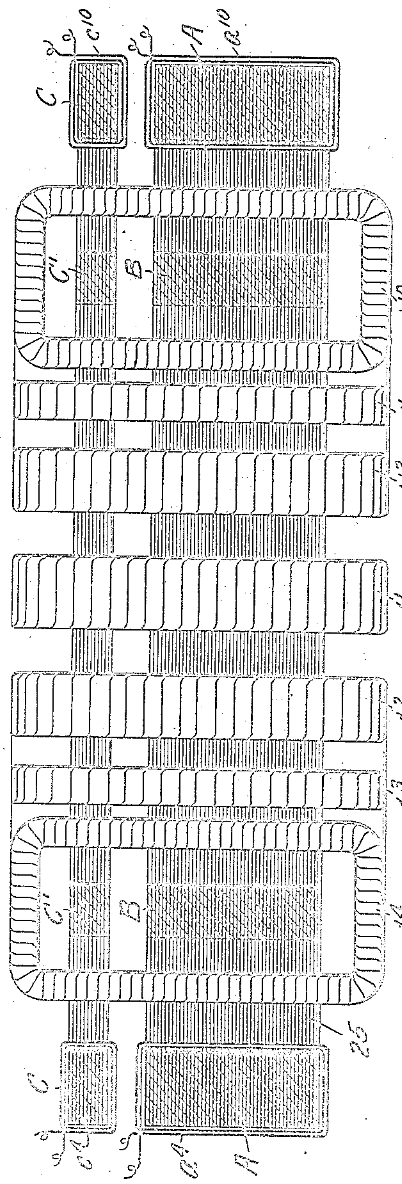
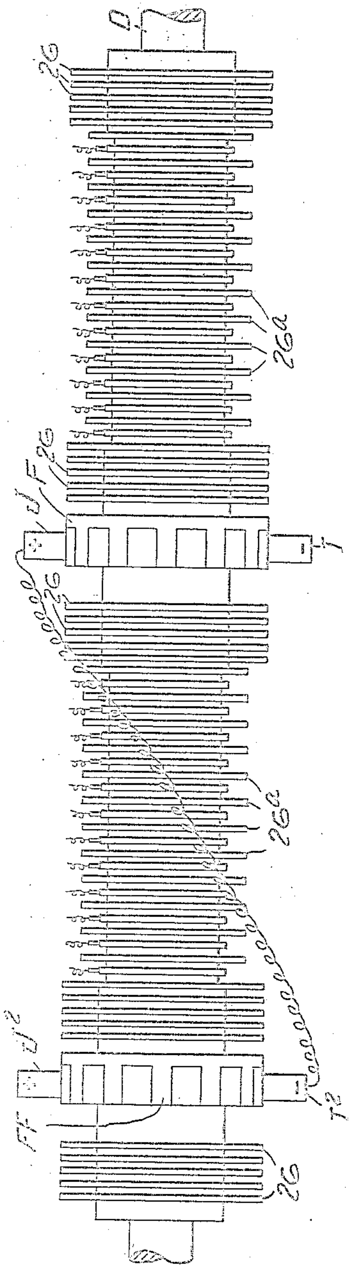


FIG. 7



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5 SHEETS—SHEET 4.

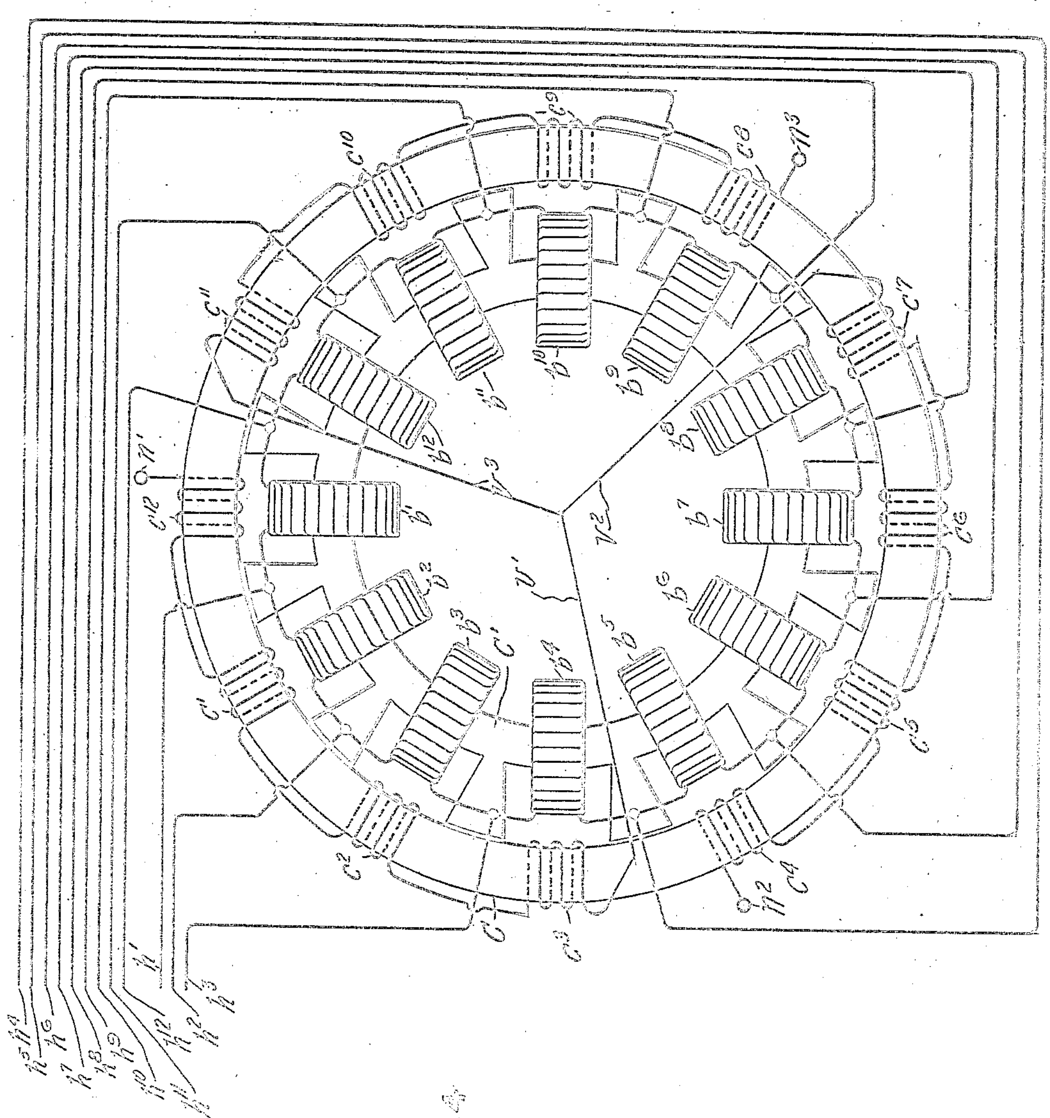

FIG. 4

WITNESSES

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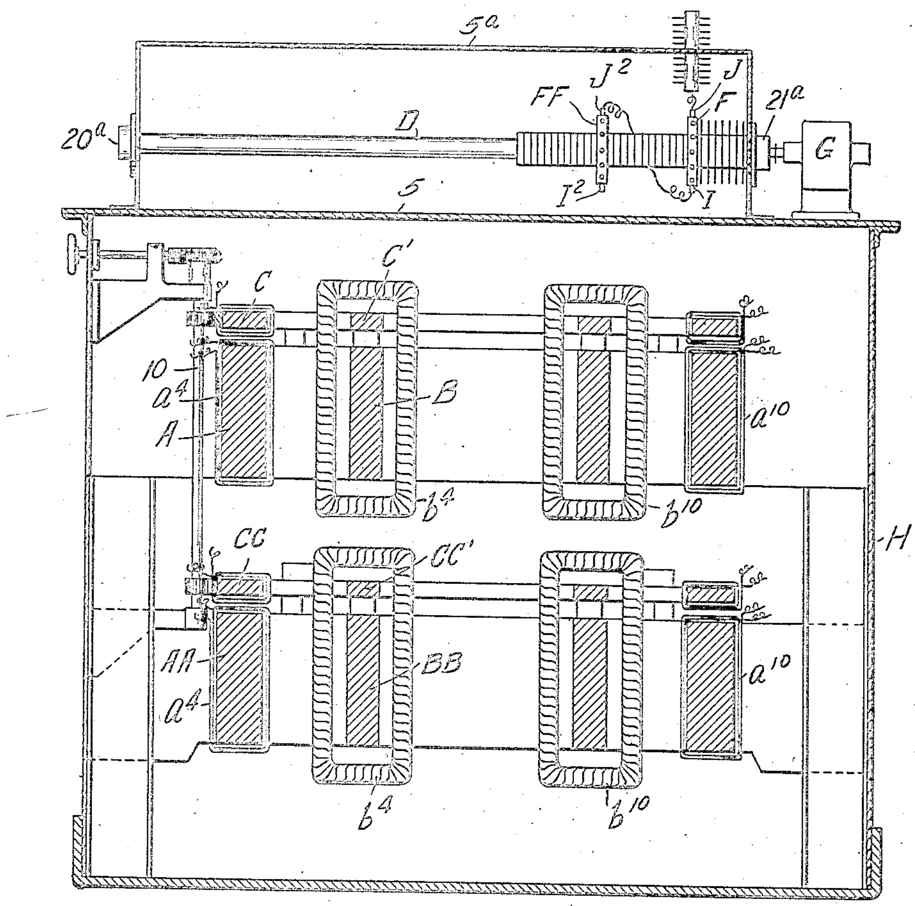
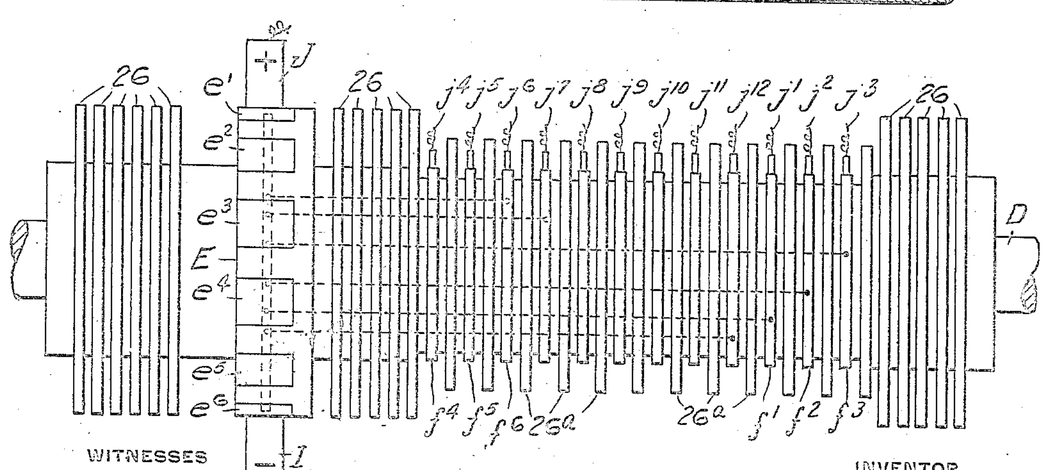
5 SHEETS—SHEET 5.

FIG. 6





WITNESSES

FIG. 5

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UNITED STATES PATENT OFFICE.

ARTHUR F. NESBIT, OF WILKINSBURG, PENNSYLVANIA.

DIRECT-CURRENT TRANSFORMER.

1,371,994. Specification of Letters Patent. Patented Mar. 15, 1921.

Application filed April 25, 1917. Serial No. 164,430.

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 the construction and arrangement of the parts of a direct current transformer for use in producing direct currents of high potential.

One object of my invention is to provide a direct current transformer which is particularly adapted for use in developing a unidirectional current of substantially constant polarity and an E. M. F. of any predetermined value, from an alternating current.

Another object of this invention is the production of a direct current transformer wherein a stationary stator and a stationary or locked rotor are employed, and whereby a unidirectional current of high potential is obtained from an alternating current of any voltage, frequency or phase combination.

Another object of my invention is to provide a transformer wherein the primary or stator and secondary or rotor cores are integrated and whereby a direct current of any desired voltage is obtainable.

A further object of the invention is to provide a high voltage, direct current transformer having improved means whereby sparkless commutation is effected, this result being accomplished by means of a commutating field which is angularly adjustable about the axis of a primary core and a secondary core.

A further object of the invention is to provide a high potential direct current transformer wherein the mass and number of the moving parts of the apparatus are reduced.

A still further object of my invention is to provide a transformer having the parts and novel constructions, arrangements, and combinations of parts illustrated in the drawings, to be described in detail hereinafter, and to be particularly pointed out in the appended claims.

As is well known to those skilled in the art, in starting induction motors with the rotor at a standstill, the rotor acts as a "locked rotor" at the instant the circuit is closed on the stator windings, and that the rotating magnetic flux set up by the polyphase currents energizing the stator coils gives rise to a magnetic field which cuts the rotor coils with the same frequency, that is to say with the frequency of the E. M. F. impressed upon the stator coils.

In constructing transformers in accordance with my invention a rotor is provided which is fixed or permanently located with reference to the stator. And to that end the laminæ of the cores preferably will be integrally formed and will be provided with a series of rectangular or approximately rectangular openings, the openings in the laminæ forming the built up cores registering to form a series of slots or gaps through which the windings of the stator and rotor coils extend.

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.

Fig. 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 Fig. 1.

Fig. 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 Fig. 2.

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

Fig. 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 Fig. 2.

Fig. 6 is an elevation, partly in section and partly diagrammatic, like that of Fig. 1, showing a horizontal transformer or transformer modified to have an axially horizontal commutator shaft and having a plurality of stator and rotor cores and commutating field cores constructed and arranged in accordance with my invention.

Fig. 7 is a detail plan showing a commutator shaft having a multiple group of commutators, slip rings and bus bars arranged thereon in accordance with my invention as constructed for use with the apparatus of Fig. 6.

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 Figs. 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 (Figs. 2 and 5) and coöperating 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 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 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 Fig. 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 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 coöperating 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, (Figs. 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 laminæ 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 Fig. 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 coils 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 also are connected in Y or in star, and the groups of coils having terminals N^1, N^2, N^3 (Fig. 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 (Figs. 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 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 Fig. 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 Fig. 5.

By splitting up the primary windings into a plurality of groups of coils, instead of one group for each phase as shown and described in connection with the apparatus of Figs. 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 a 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}, and 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.

In the modified construction shown in Fig. 6 the grouping of the coils on the primary or stator cores, the secondary or locked rotor cores and the primary commutating field cores, is the same as in Figs. 1, 2, 3, and 5.

The modified apparatus, however, has two separate stator cores A, and A—A, two rotor cores B and B—B, two primary field cores C and CC and two secondary field cores C^1 and CC^1. Each rotor core has its series of cores a^1, a^2, a^3, etc., each stator core its coils b^1, b^2, b^3, etc., and each primary field core its windings or coils c^1, c^2, c^3, etc., and each stator and rotor unit has its complement of slip rings f, f, f, etc.

The commutator shaft D being horizontal, is mounted at its ends in bearings 20^a, 21^a which are secured on the ends of the high pressure cover 5^a for the commutators, the cover being supported on the cover or lid 5 for the tank H. The synchronous motor G for driving the commutator shaft D also is mounted on the tank cover or lid 5, the commutator shaft being directly connected to the armature shaft of the motor G. Each of the angularly adjustable, commutating field cores C and CC in the apparatus of Fig. 6 preferably is geared to the vertical shaft 10 of a single adjusting mechanism used therewith so that the commutating field cores and coils thereon will be adjusted in unison, in the manner shown in Fig. 5. The commutating field cores C may be arranged to be adjusted separately and independently, however, when found necessary or desirable. In the apparatus of Fig. 6 two commutators or groups of commutator segments F and F—F will be employed one for each of the two stationary or locked rotor cores B, B—B, and the brush J^2 on one terminal of the commutator F—F will be connected by a lead to the terminal I of the opposite sign for the commutator F while the brush J on the commutator F and brush I^2 on one terminal for the commutator FF will lead to the apparatus of utilization of the generated unidirectional current.

The operation of my improved apparatus will now be described. A source of alternating or multi-phase current will be connected by means of suitable conductors to the terminals m^1, m^2, and m^3 for the three groups of coils a on the stator core A, and to the terminals n^1, n^2, and n^3, for the similarly arranged groups of coils C on the angularly adjustable commutating field core C, and also to the terminals for the synchronous motor G. When current is supplied in this manner the three series of primary coils a on the stator A are energized and thereby caused to produce a two-pole rotating magnetic field in the cores A and B.

The flux of this rotating magnetic field passes progressively through the series of coils of the secondary or locked rotor core B by means of the magnetic path provided by the integrated cores A and B and induces electromotive forces in the coils b^1, b^2, etc., of the secondary or locked rotor core B. The time phase relations of the induced electromotive forces in the coils b^1, b^2, etc. relative to one another will be proportionate to the relative angular displacement of these coils b^1, b^2, etc.

These secondary or locked rotor coils b^1, b^2, etc., are spaced or positioned in regard to one another to have an equal angular displacement and the terminals of the electrically adjacent coils are connected together so that the twelve coils form a complete series similar to a closed Gramme ring.

At the same time the multi-phase current is supplied to the terminals n^1, n^2, and n^3 of the groups of coils c on the primary commutating field core C, and the coils c^1, c^2, etc., also are energized and are caused to produce a two-pole rotating magnetic field in the cores C and C^1.

The flux of this rotating magnetic field also passes progressively through the secondary or locked rotor coils b^1, b^2, etc., through the medium of the magnetic path provided by the cores C and C^1.

The rotary magnetic field in the commutating field cores C, C^1, however, is not in space phase relation with the primary rotating magnetic field induced in the stator coils a^1, a^2, a^3, etc., but leads or lags behind it by approximately 90 degrees, so that in this way the desired sparkless commutating conditions are obtained. As the displacement of the group of commutating field coils c^1, c^2, c^3, etc., is not permanent but may be regulated and controlled angularly with respect to the coils of the stator core A by means of the adjusting mechanism which has been described, non-sparking commutating conditions equal to those of the most modern type of standard direct current apparatus are obtained with my improved transformer.

When found desirable or necessary secondary field coils may be added to the core C^1 which will produce a rotating magnetic field at approximately 90 degrees magnetic displacement relative to the field obtained in the primary coils c on the core C so as to obtain sparkless commutation.

The leads h^1, h^2, etc., which are connected at one end to the joined terminals of the electrically adjacent coils b^1 and b^2, b^2 and b^3, etc., extend each to its individual slip ring f^1, f^2, f^3, etc., (through its ring i^1, i^2, i^3, etc., when the rings are employed) and through the slip rings f^1, f^2, f^3, etc., and permanent leads l^1, l^2, etc., to its appropriate commutator segment e^1, e^2, e^3, etc., forming the commutator or commutating group E on the shaft D, and as the synchronous motor G for driving the commutator shaft is connected to a common source of alternating multi-phase current the commutator will be rotated synchronously with the current induced in the coils of the rotor, stator and commutating field cores. The E. M. F.'s induced in the secondary or locked rotor coils b^1, b^2, b^3, etc, when connected in the manner described above, will be superposed one upon the other and be rectified to produce a unidirectional E. M. F., the value of which is dependent upon the geometrical sum of the individual E. M. F.'s induced in the secondary or locked rotor coils.

It will, of course, be understood that the synchronous motor is used because it must rotate in step with the generator or transformer supplying current to it and to the coils of my improved transformer.

Modifications in the constructions and arrangements of the parts may be made. Obviously the primary and secondary cores and coils therefor may be interchanged to position the primary windings on the inside and secondary windings on the outside instead of as shown, and the commutating field cores may be similarly interchanged and also other combinations may be formed so long as the same magnetic circuit is embraced by the coils, without departing from my invention as defined in the appended claims.

I claim:—

1. A transformer comprising a main field having integrated primary and secondary cores and a plurality of coils on said primary and secondary cores, a commutating field having a core and a plurality of coils on said core, 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, 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 and a plurality of coils on said primary and secondary cores, a commutating field having a core and a plurality of coils on said core, said fields being displaced approximately 90 degrees in phase and said commutating field being angularly adjustable about the axis of said primary and secondary core, a commutator group connected to the coils of said secondary core, collectors for said commutator group, and means for adjusting said commutating field angularly relative to said primary and secondary cores.

3. A transformer comprising a main field having integrated primary and secondary cores with windings on said primary core and on said secondary core, a commutating field having an adjustable core and windings on said adjustable core, said fields being displaced approximately 90 degrees in phase and said adjustable core being axially alined and being axially movable relative to the main field core in adjusting the commutating field, a rotating commutator group, and means for actuating said commutator group.

4. A transformer comprising a main field having integrated primary and secondary cores with windings on said primary core and on said secondary core, a commutating field having an adjustable core and windings on said adjustable core, said fields being displaced approximately 90 degrees in phase and said adjustable core being axially alined and being axially movable relative to the main field core in adjusting the commutating field, a rotating commutator group and a synchronous motor for actuating the commutator group, said motor being connected to the source of current for the windings on said primary core.

5. A transformer comprising a main field having cores and coils forming a stator and locked rotor, and an adjustable commutating field having a core and coils, said fields being in axial alinement and being displaced approximately 90 degrees in phase, a rotating commutator group connected to the coils of the locked rotor, means for adjusting said commutating field angularly relative to the main field, and means for actuating said rotating commutator group.

6. A transformer comprising a main field having cores and coils forming a stator and locked rotor, and an adjustable commutat-

ing field having a core and coils, said fields being in axial alinement and being displaced approximately 90 degrees in phase, a rotating commutator group connected to the coils of the locked rotor, means for adjusting said commutating field angularly relative to the main field and a synchronous motor for actuating said rotating commutator group, said motor having terminals connected in parallel with the primary coils of said stator.

7. A transformer comprising a main field having integrated primary and secondary cores, and a plurality of coils on said cores, a commutating field having a core and a plurality of coils thereon, said fields being displaced approximately 90 degrees in phase and said commutating field being angularly adjustable about the axis of the primary and secondary cores of said main field, and each corresponding group of the primary and stator coils being similarly connected to a source of power, a commutator group connected to the coils of said secondary core, and collectors for said commutator group.

In testimony whereof I have hereunto set my hand.

ARTHUR F. NESBIT.