V. A. FYNN.

ALTERNATING CURRENT MOTOR.

APPLICATION FILED JAN. 29, 1909.

967,361.

Patented Aug. 16, 1910.

4 SHEETS—SHEET 1.

Fig.1.

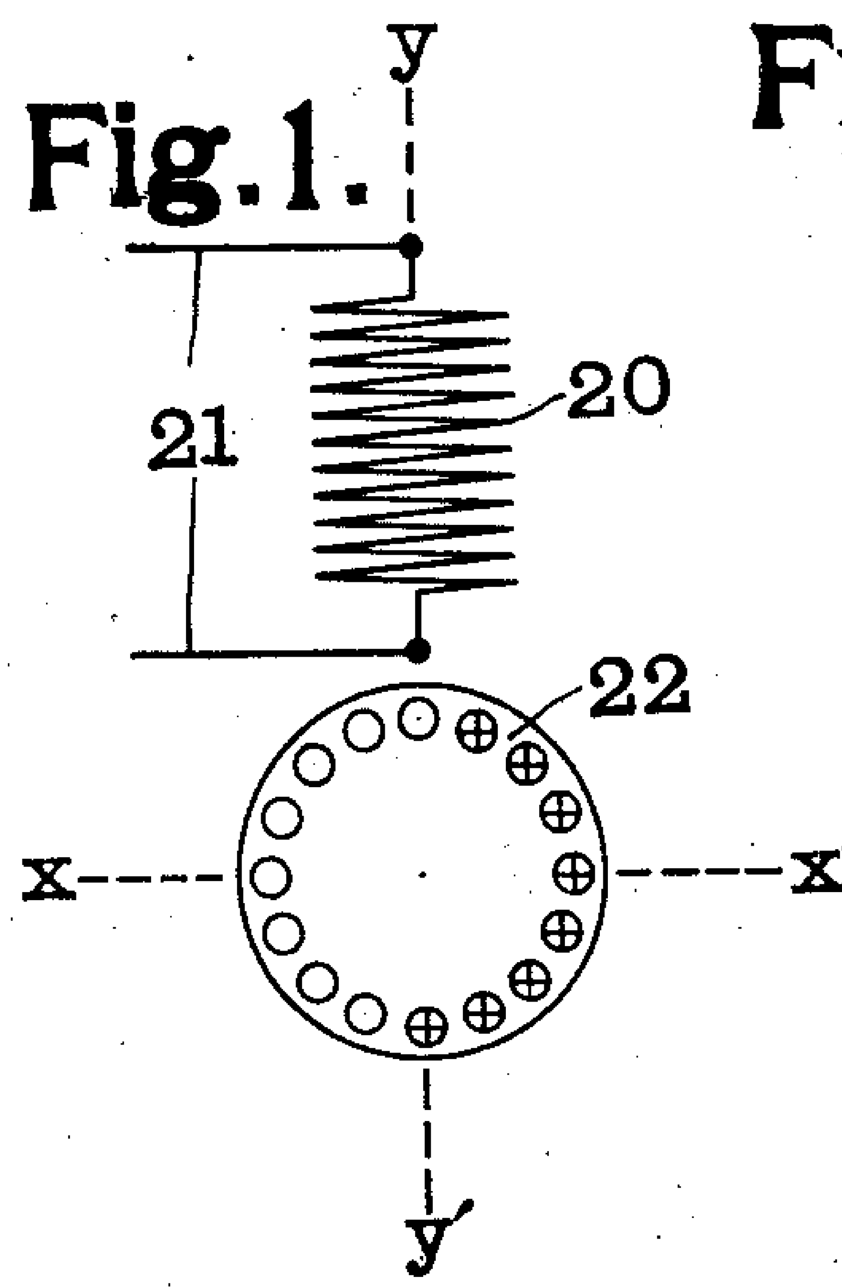

Fig.2.

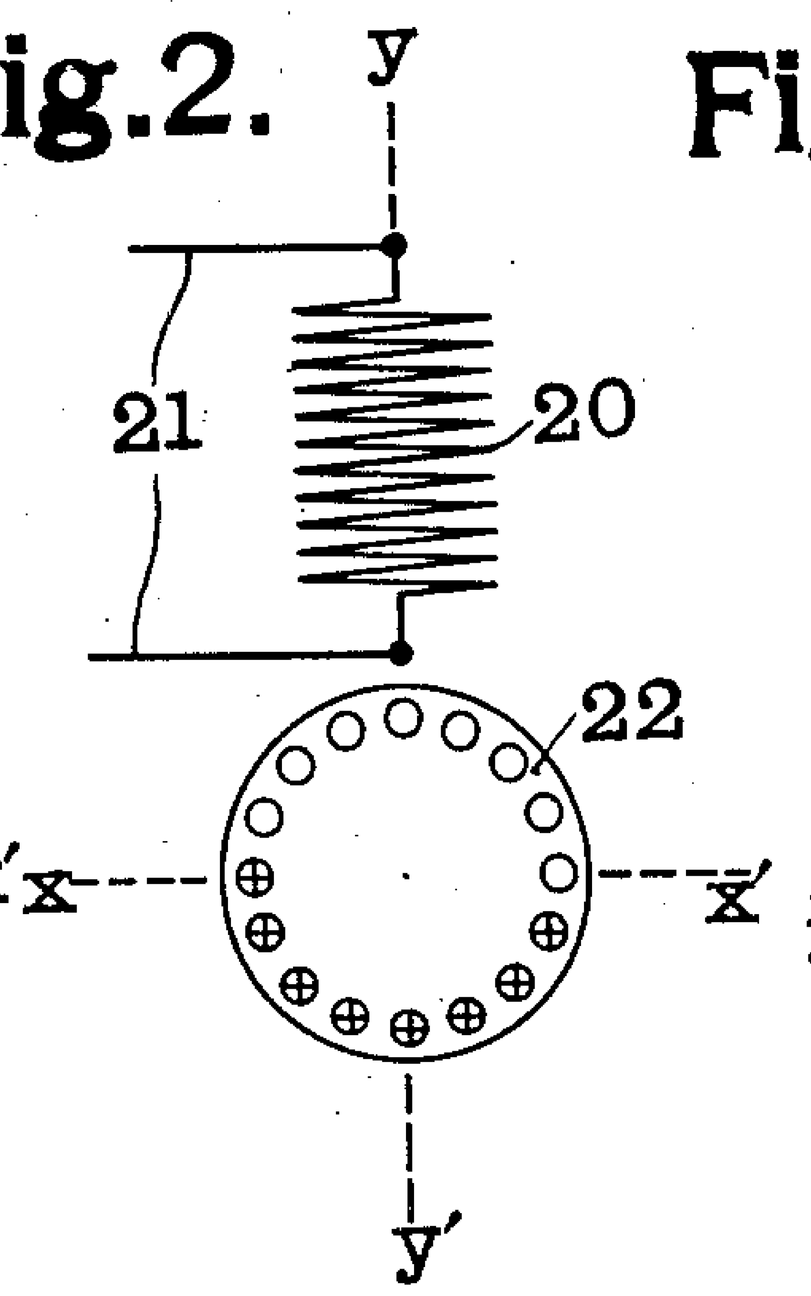

Fig.3.

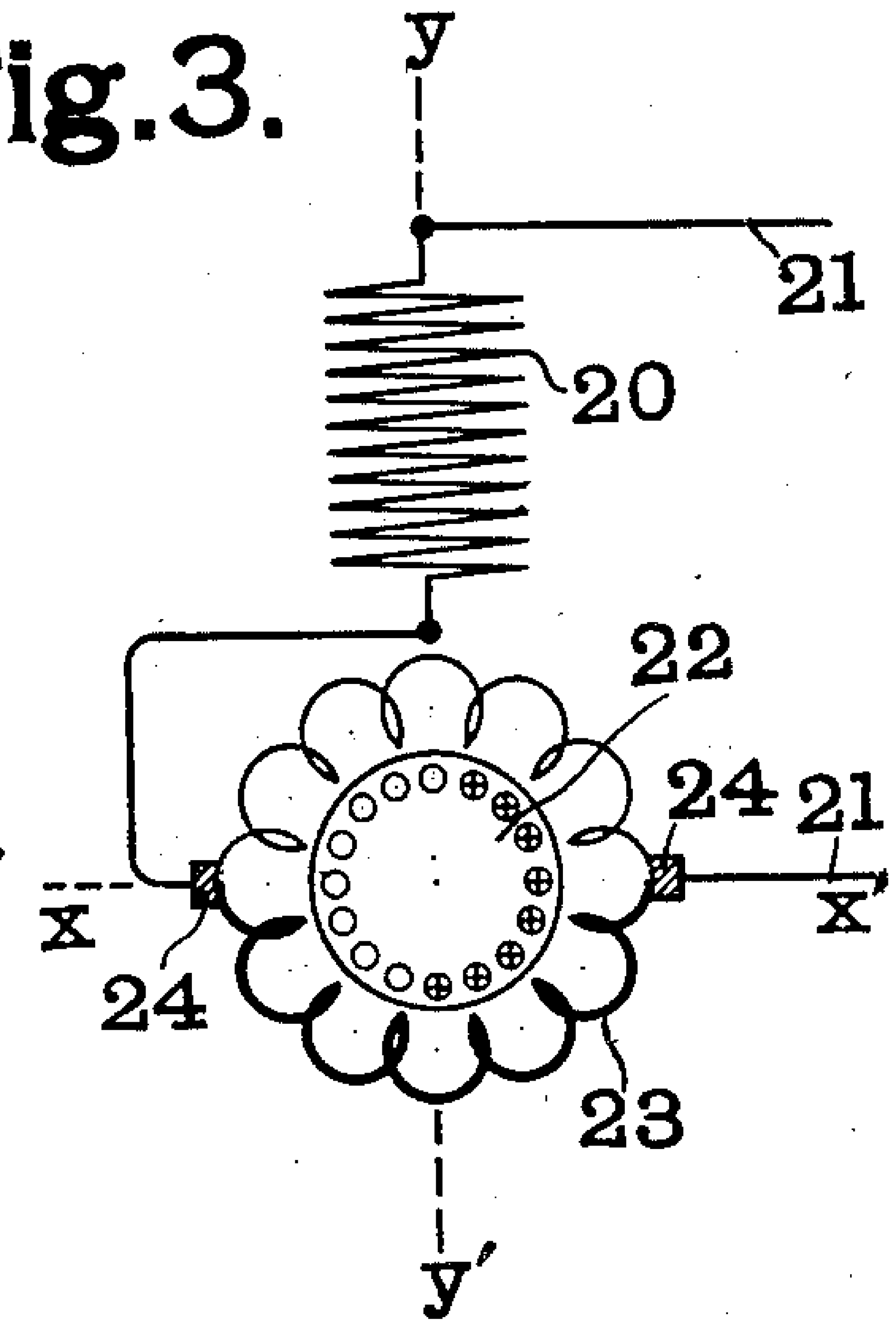

Fig.5.

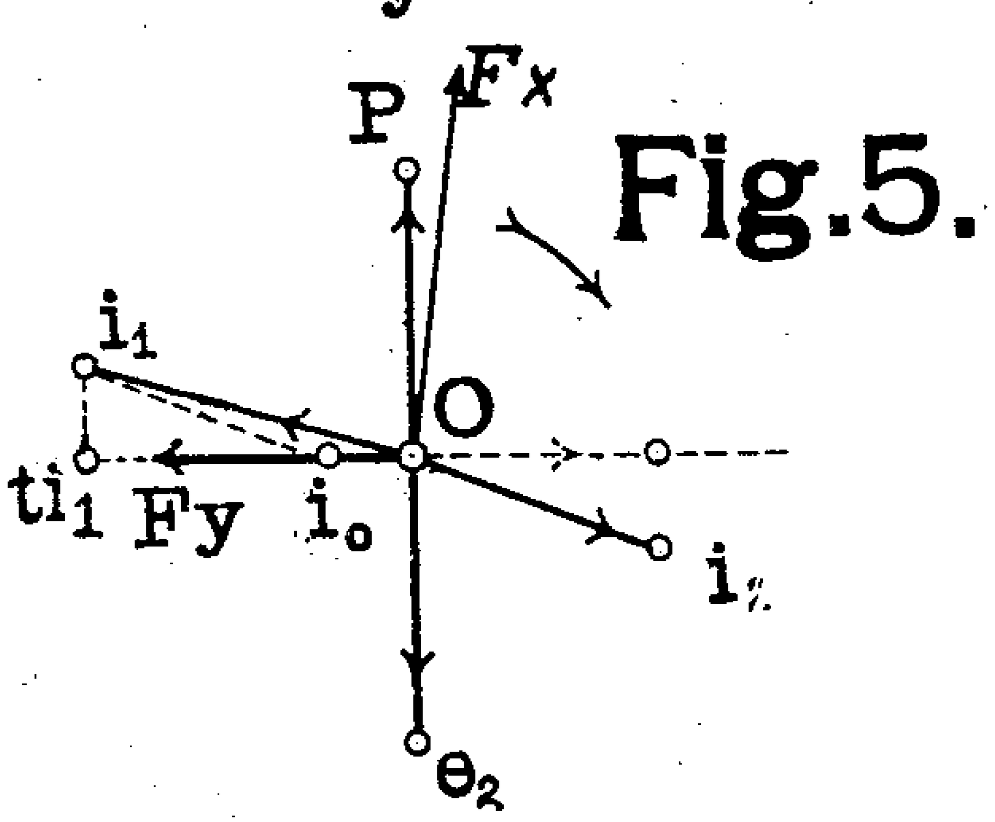

Fig.6.

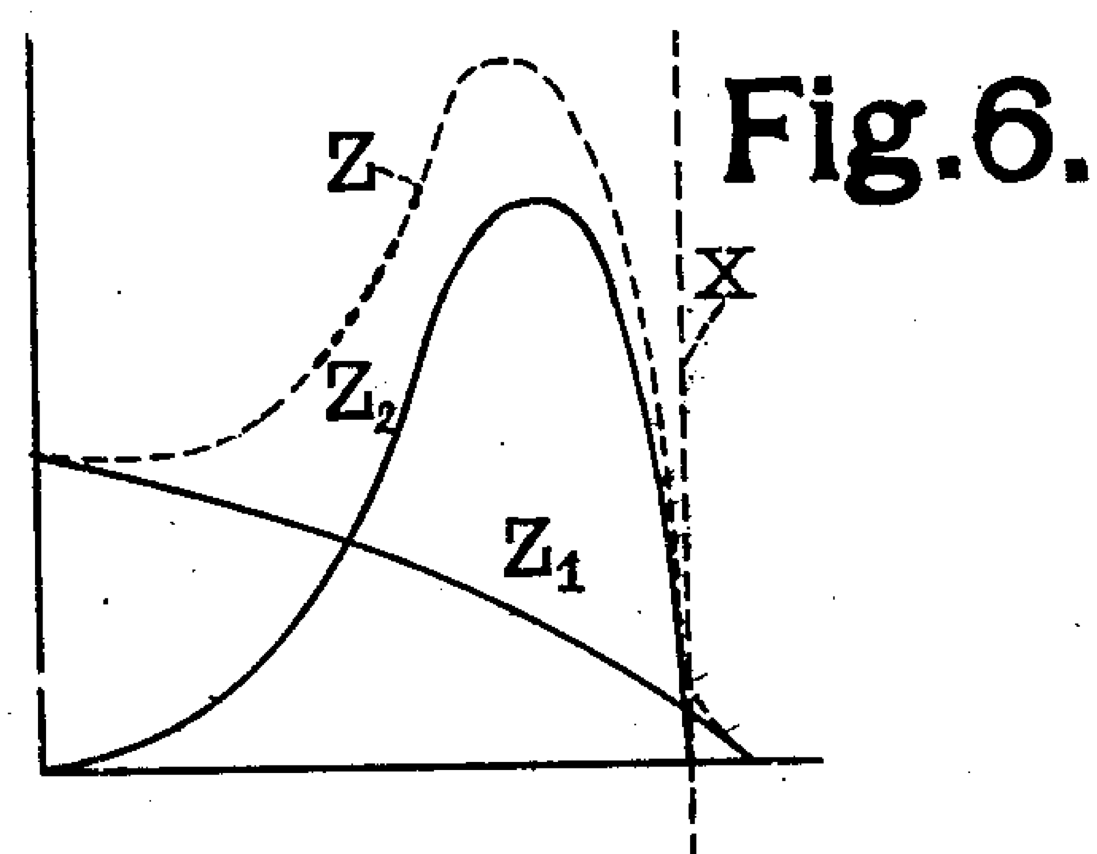

Fig.17.

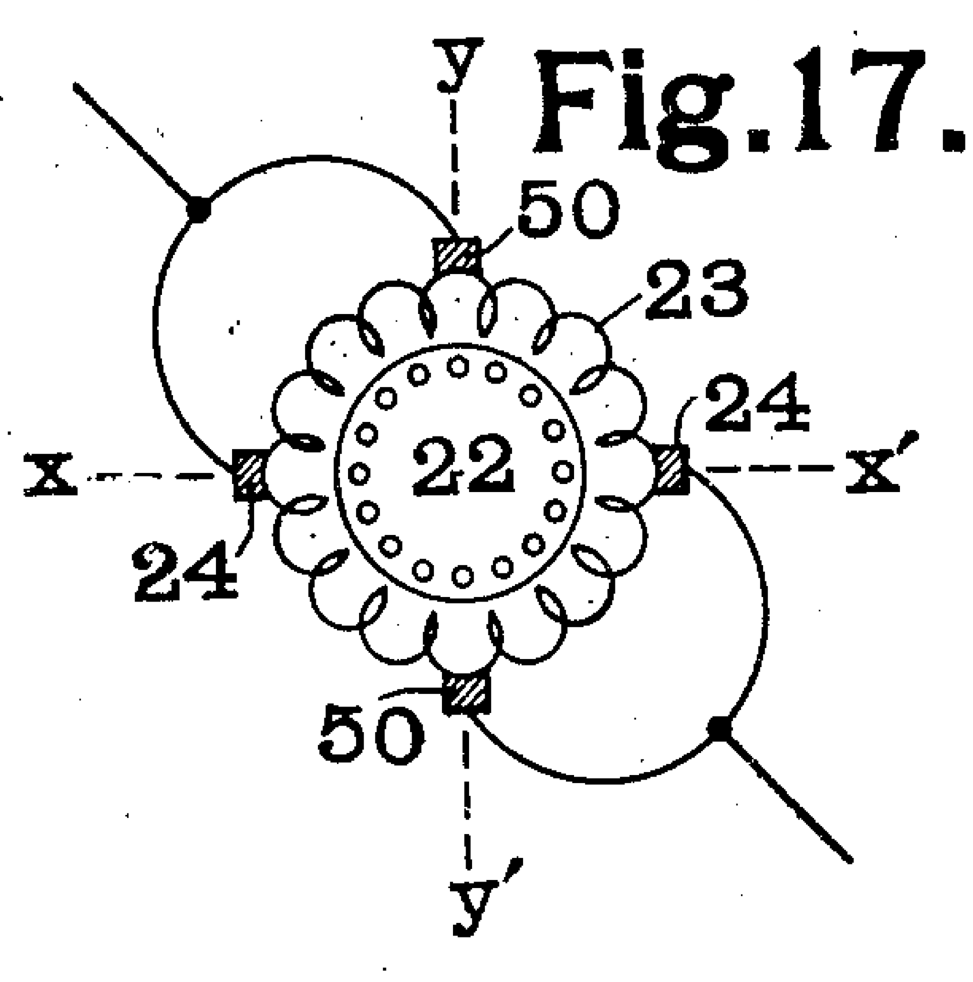

Fig.18.

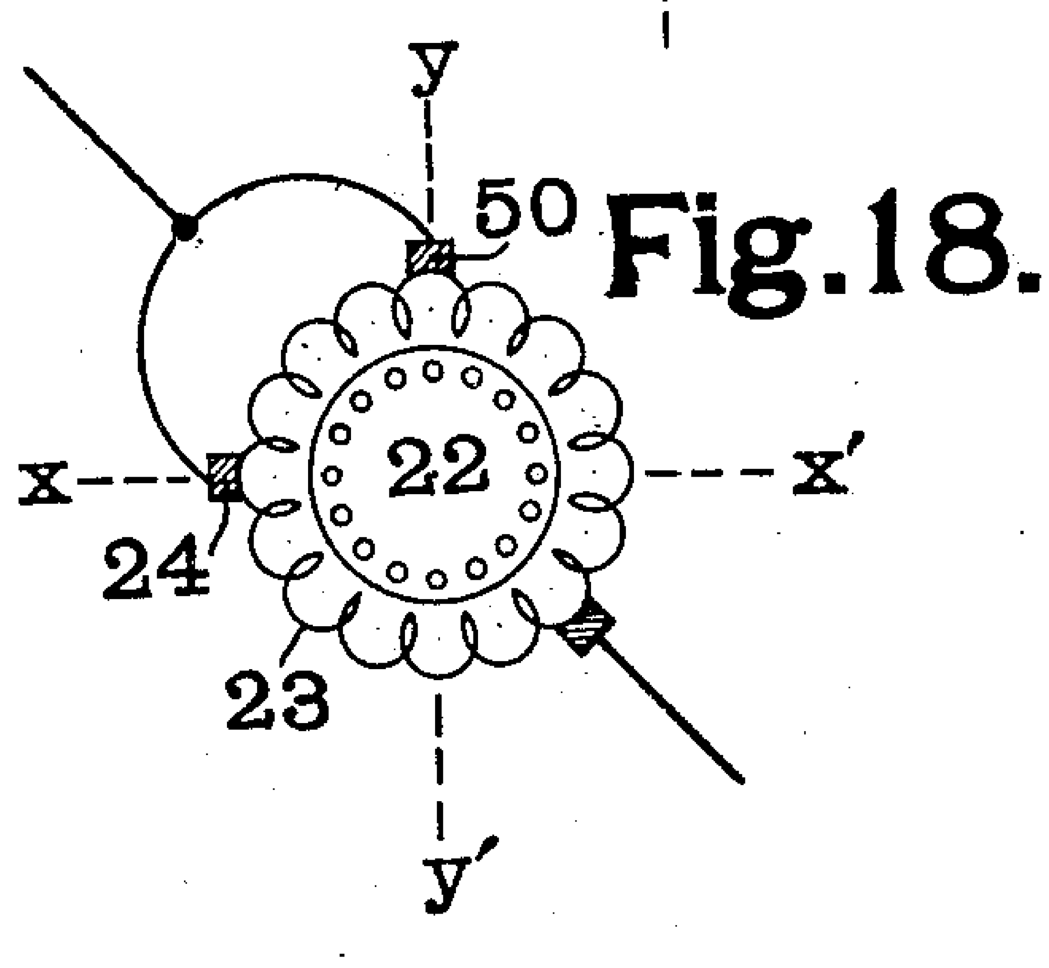

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Fig. 7.

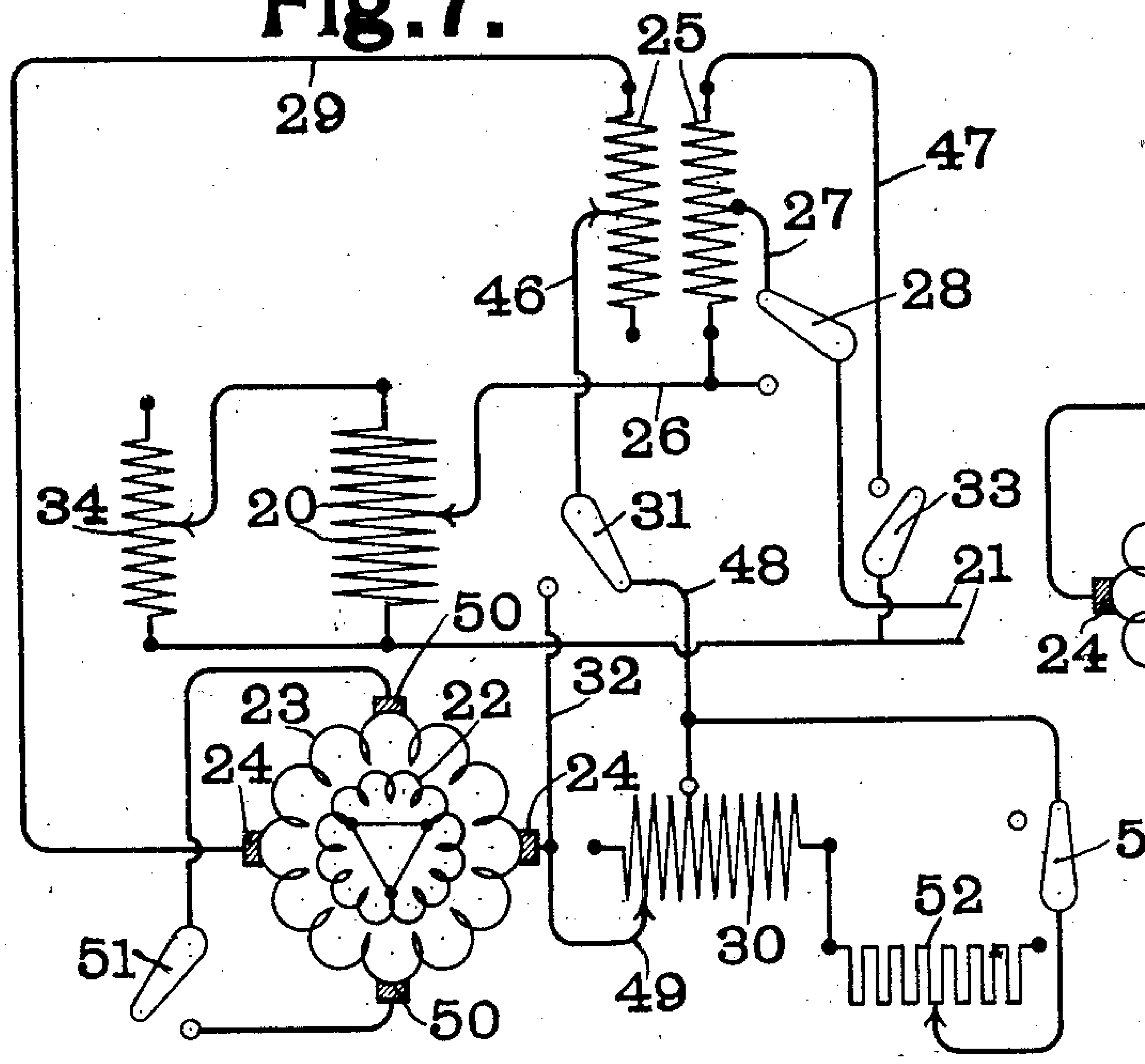


Fig. 9.

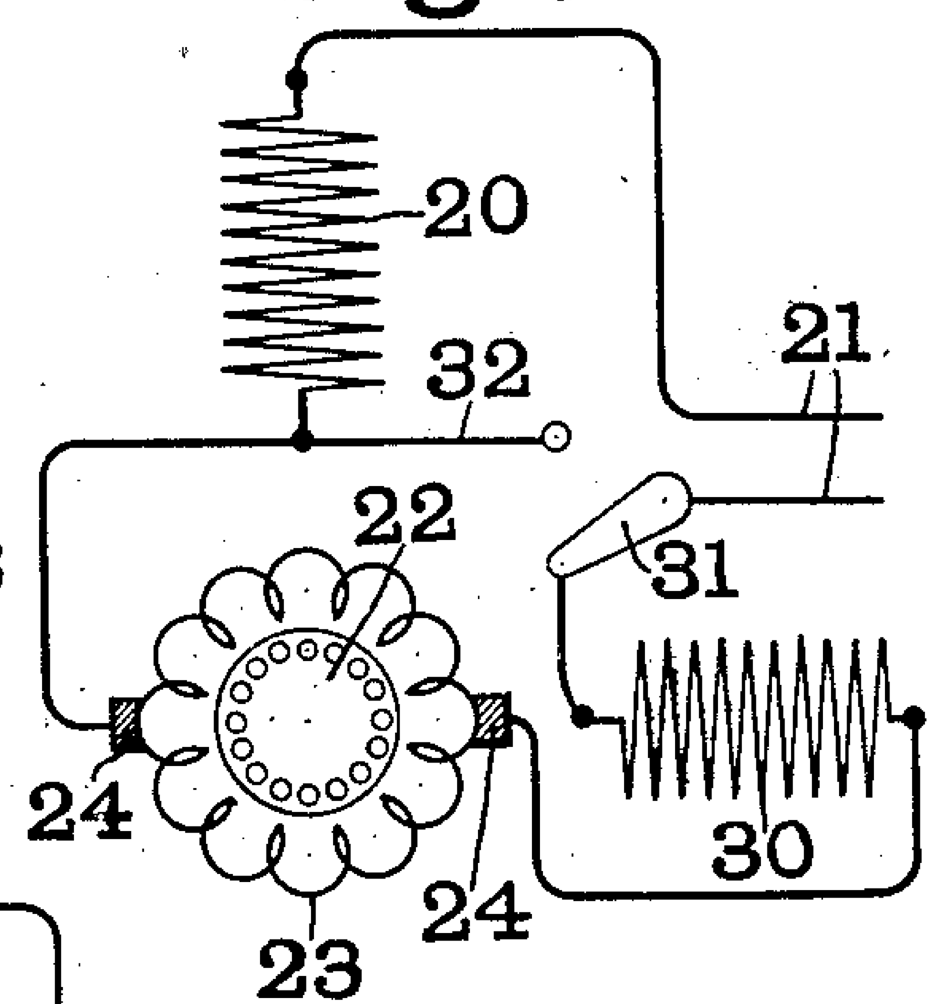


Fig. 8.

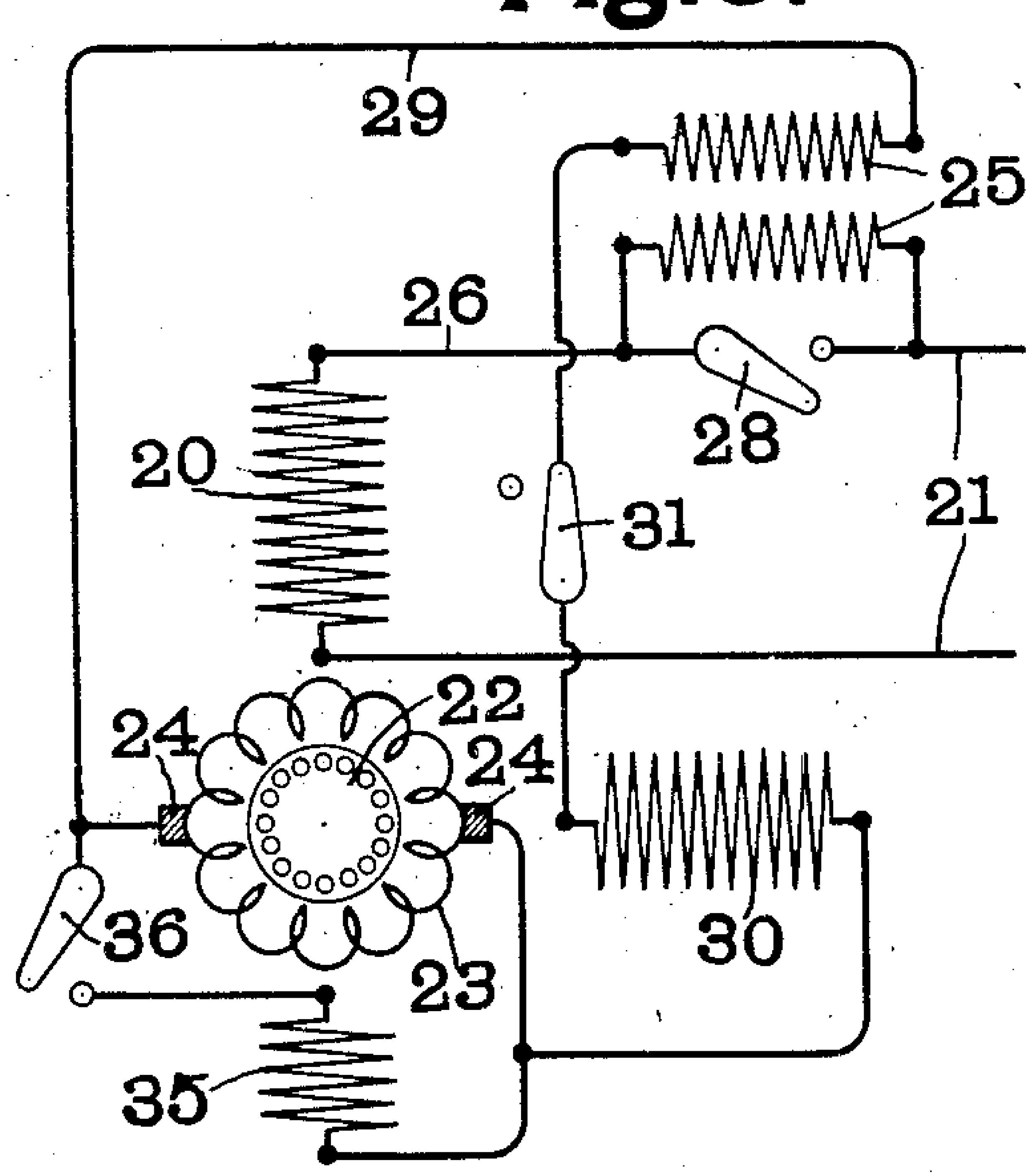
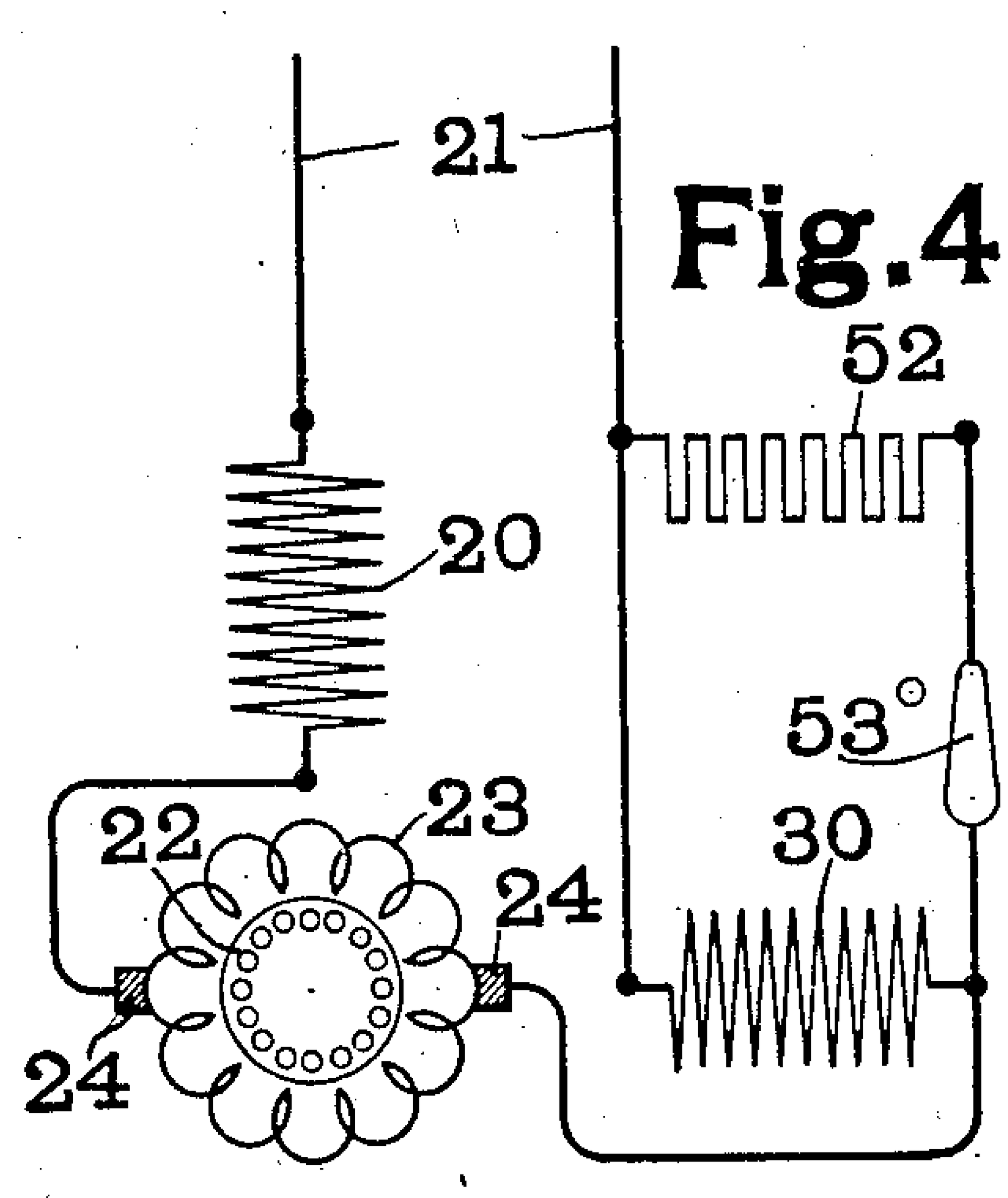


Fig. 4.



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4 SHEETS—SHEET 3.

Fig.10.

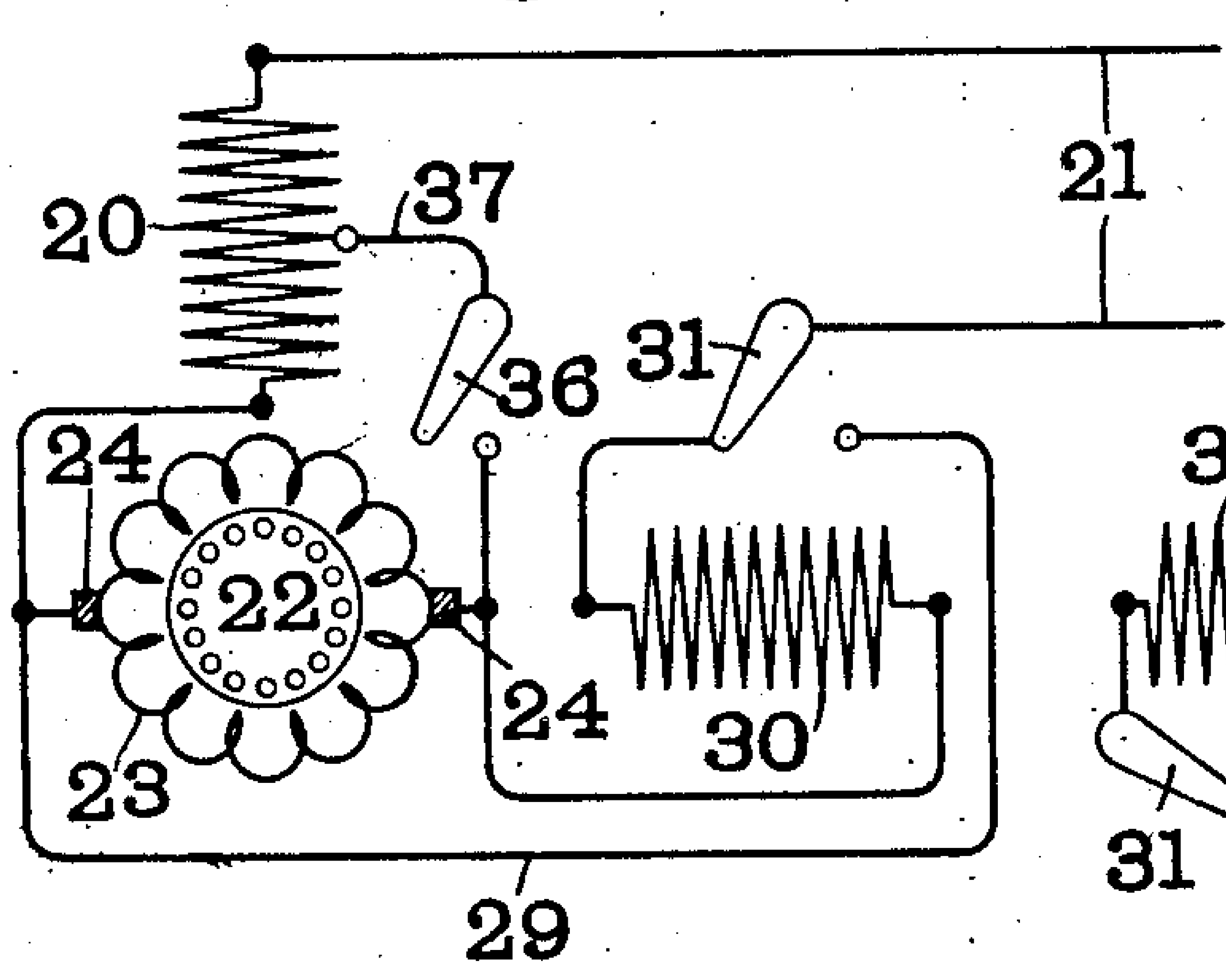


Fig.15.

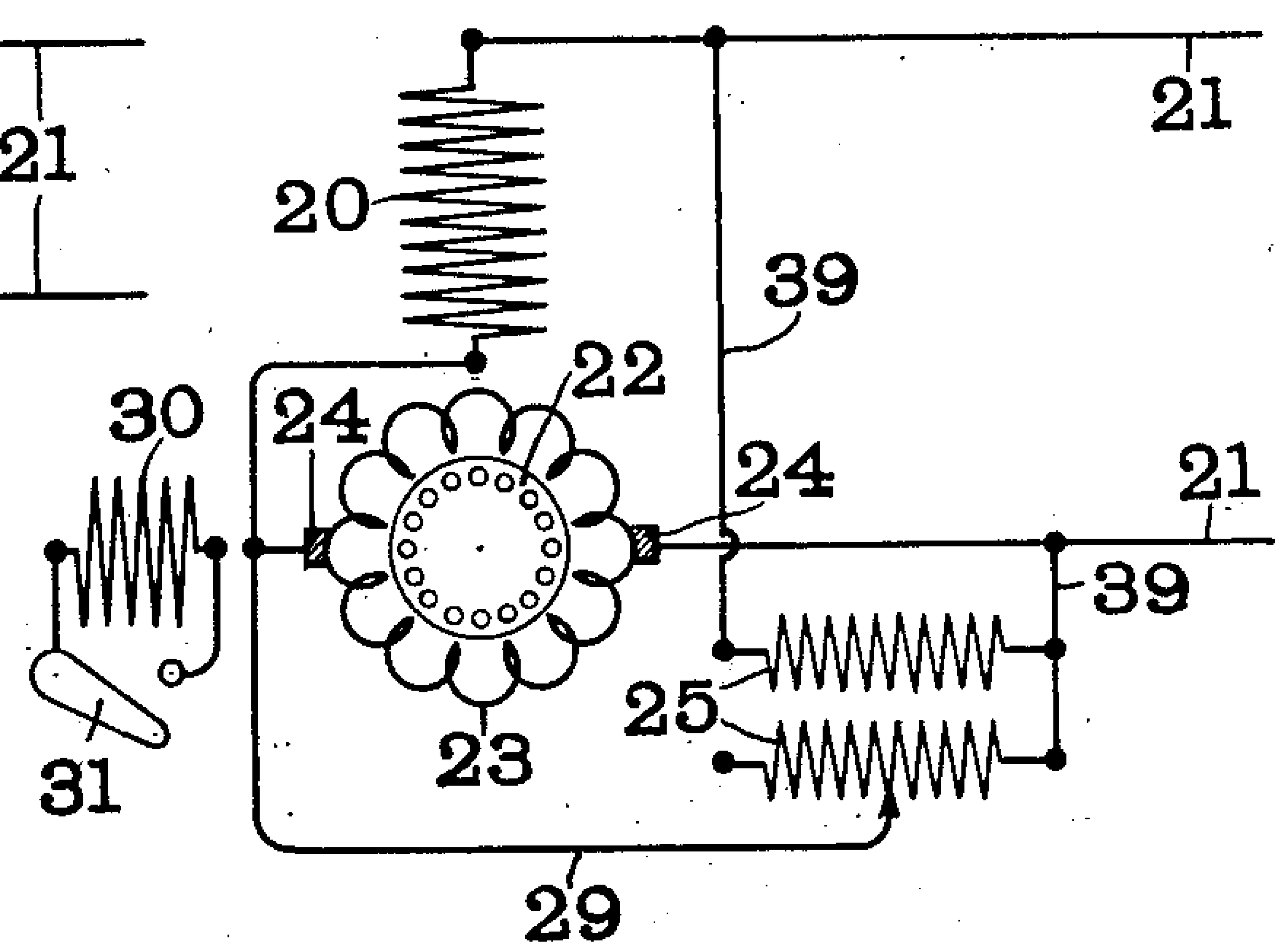


Fig.11.

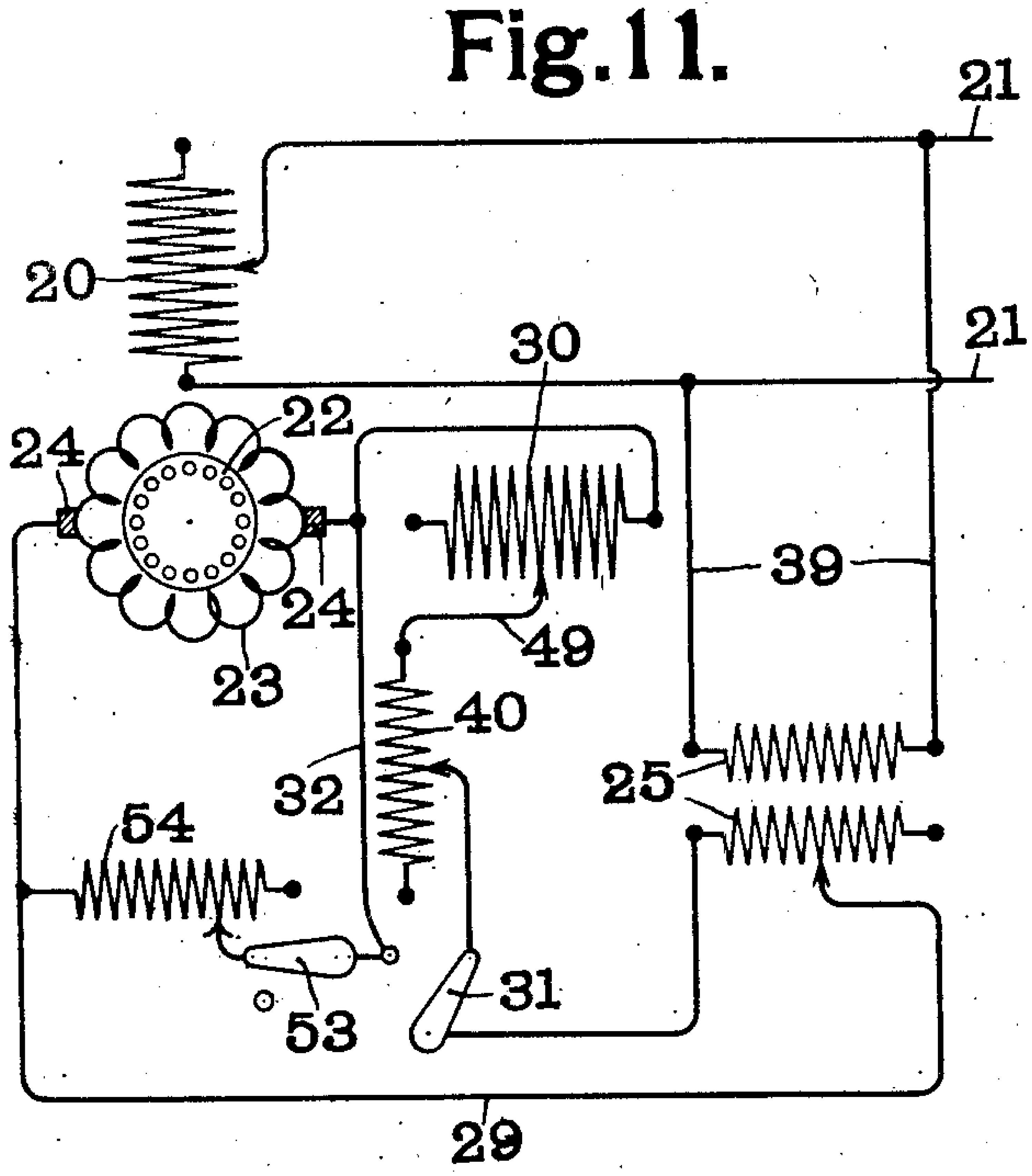
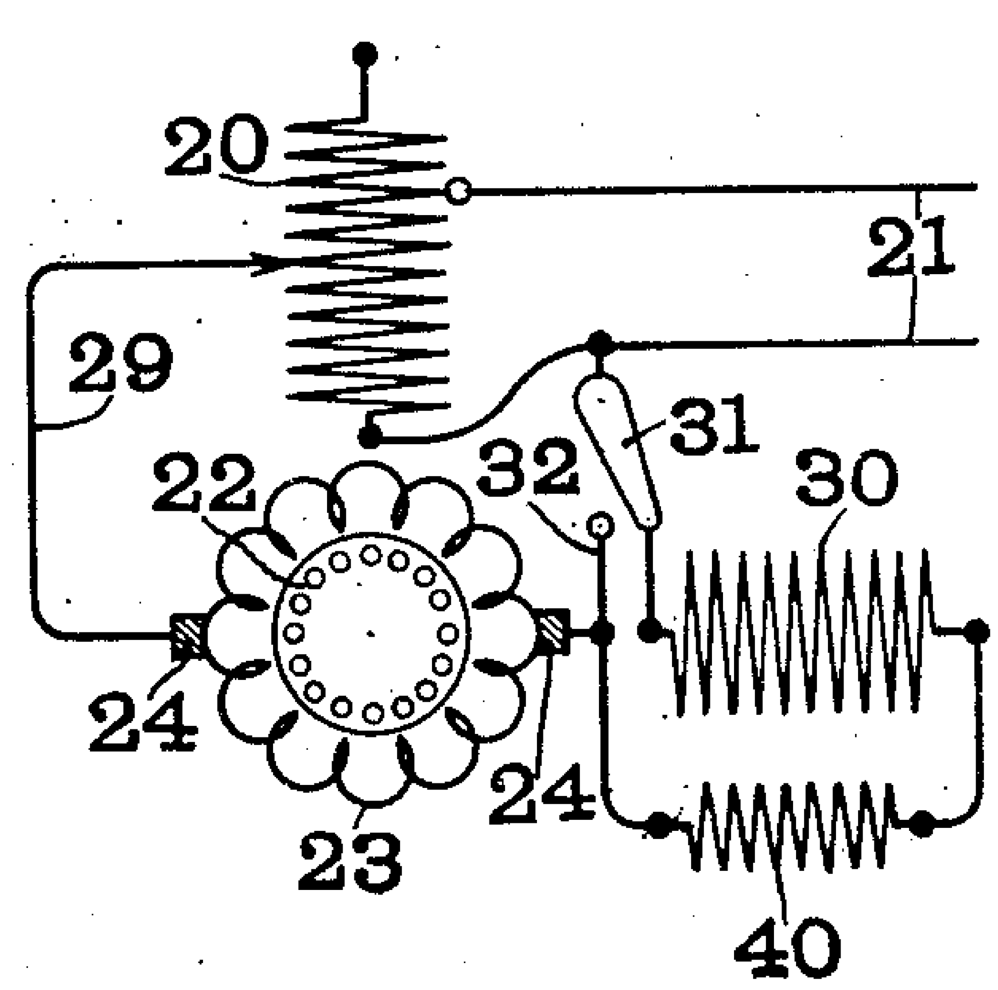


Fig.12.



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4 SHEETS—SHEET 4.

Fig.13.

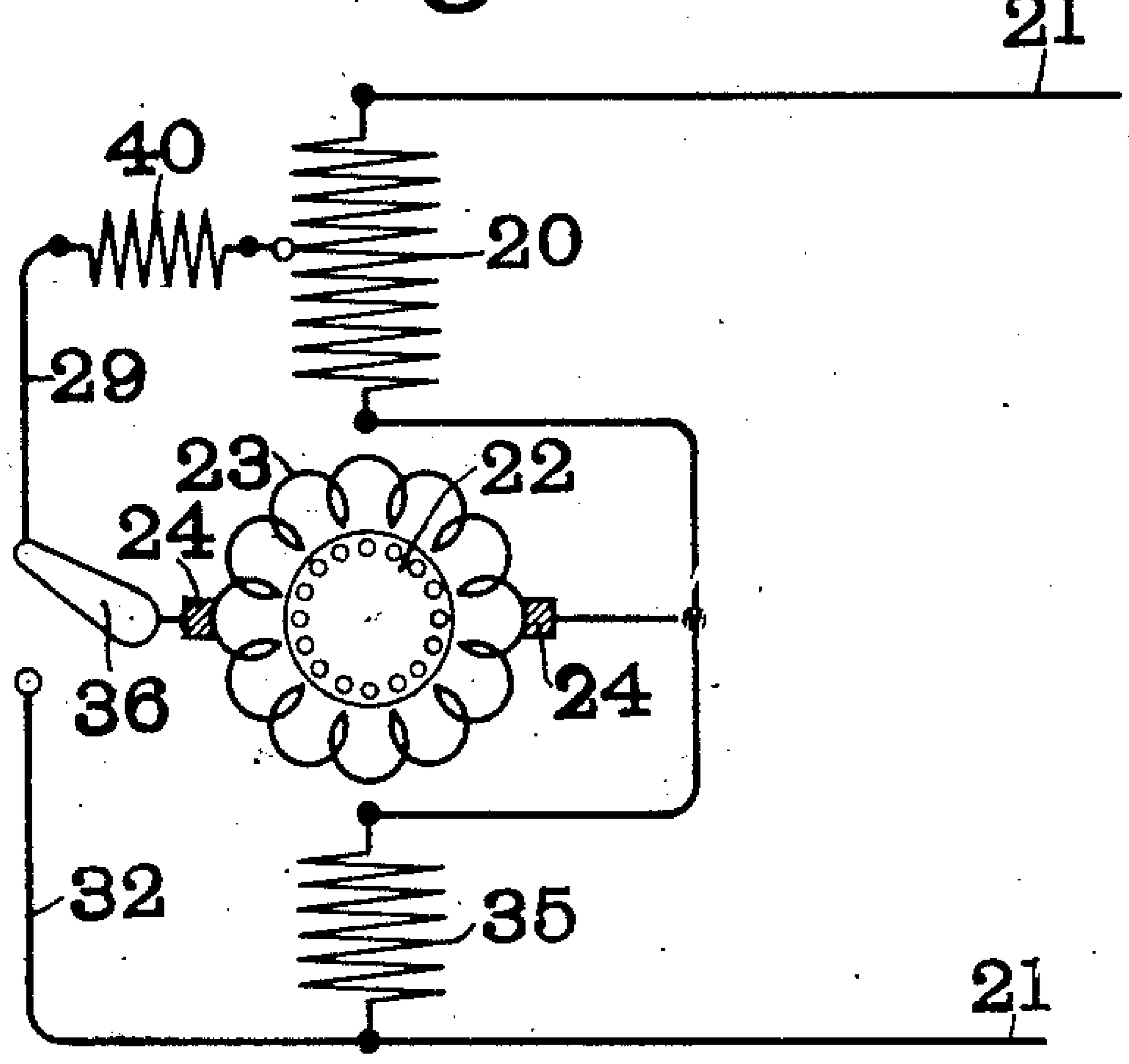


Fig.14.

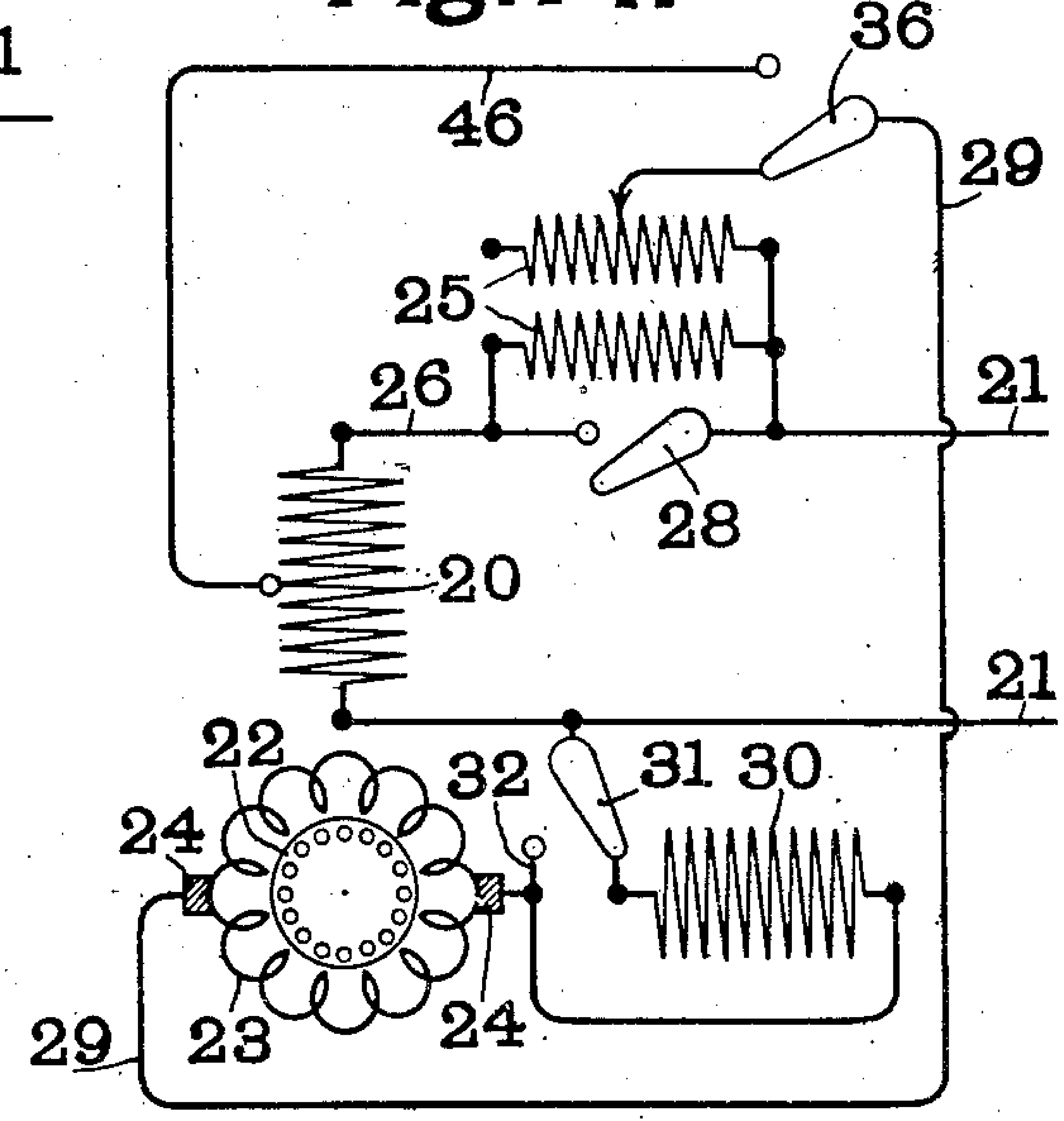


Fig.19.

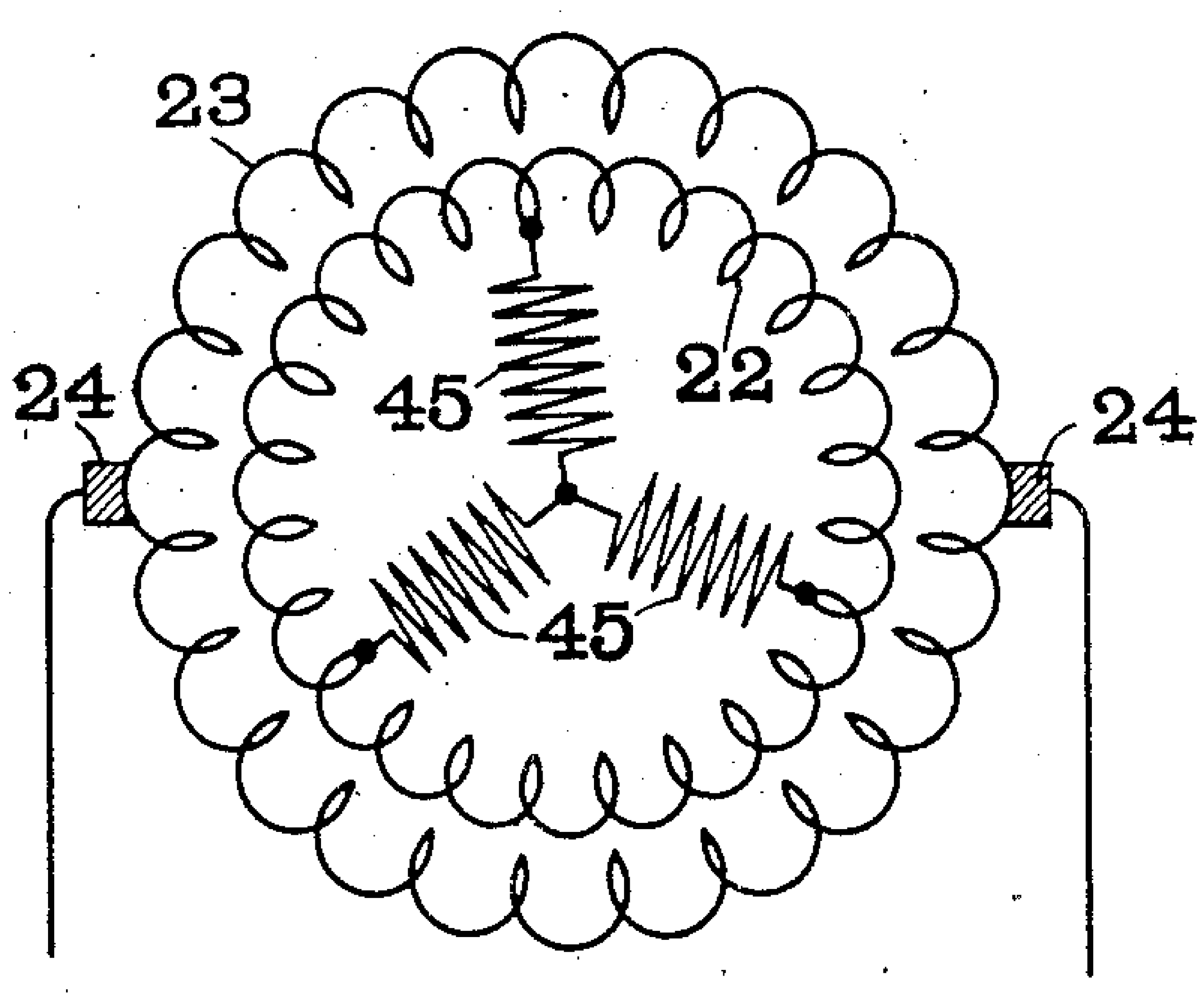
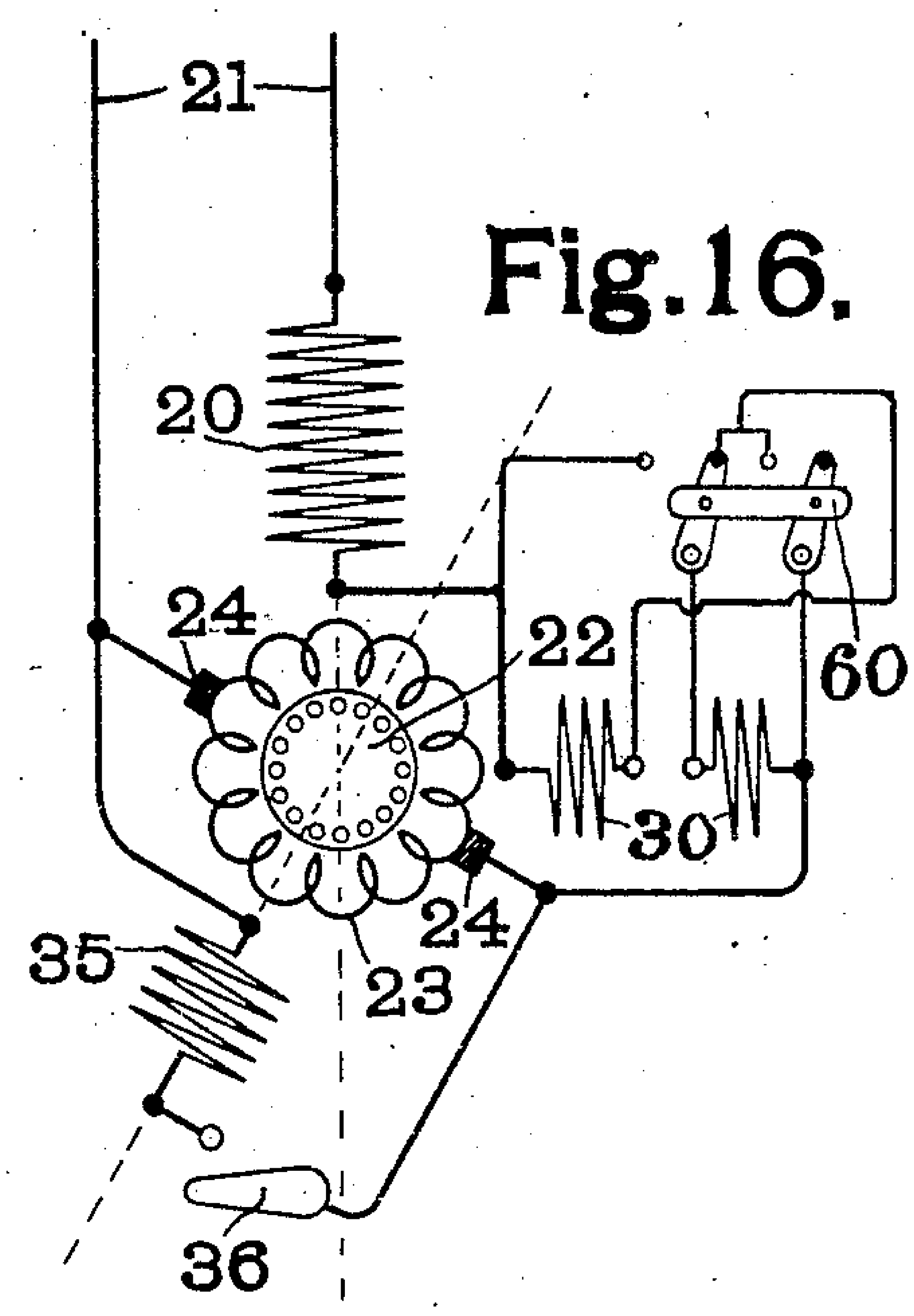


Fig.16.



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ALTERNATING-CURRENT MOTOR.

967,361. Specification of Letters Patent. Patented Aug. 16, 1910.

Application filed January 29, 1909. Serial No. 474,983.

To all whom it may concern:

Be it known that I, VALÈRE ALFRED FYNN, a subject of the King of England, residing at London, England, have invented a certain new and useful Alternating-Current Motor, of which the following is such a full, clear, and exact description as will enable any one skilled in the art to which it appertains to make and use the same, reference being had to the accompanying drawings, forming part of this specification.

My invention relates to alternating current motors of the single phase induction type, having an induced winding closed on itself permanently and independently of a commutator.

The objects of my invention are to provide improved means for starting motors of the type above referred to; to simplify and to reduce to a minimum those changes in connections of the motor, which are absolutely necessary after the latter has reached its normal speed; to make the transition from the starting to the running condition without a material reduction in the magnitude of the torque and quite independent of the operator or of any switching devices, be these operated automatically or by hand; to provide improved means for compensating the motor after the running condition has been attained; to improve the commutation of the machine; to prevent "racing", and to fully utilize all the copper on the induced member for the production of a useful torque, thus increasing the efficiency of the machine.

It has heretofore been impossible to start motors of the type referred to, with a powerful torque and a reasonably small current consumption, as compared to the current consumption at full load, without opening the winding closed on itself at the moment of starting, or without impairing the efficiency and the characteristic preperties of said winding under normal running conditions. If the winding closed on itself is opened during the starting period, a device must be provided for closing that winding when a certain speed has been reached. If this device is not operated in time, the motor is liable to "race"; in any case such a device, especially if automatic, is costly and liable to get out of order. If the starting is accomplished by impairing the efficiency of the winding closed on itself, for instance by placing it in slots placed at some distance from the air-gap, or by inserting unduly large impedances of any kind, then the speed of such a motor under load is subject to material variations, and its output is greatly reduced.

By "winding closed on itself", as used herein, is meant a winding of any desired description containing any desired amount of impedance, *i. e.* ohmic resistance, reactance or capacity but permanently closed on itself along at least one axis per pole pair and in such a manner that currents may be induced therein by the main inducing winding. Thus a 3 phase winding is closed on itself along 3 axes per pole pair, whereas a squirrel cage winding is closed along as many axes per pole pair as there are slots per pole, and so forth. The said winding is to be closed on itself independently of any commutating device, and along axes which retain the same relative position with respect to any given point of the induced member, whether the latter revolves or not.

Now according to this invention, motors of the type herein referred to may be started with a powerful torque per ampere without any possibility of "racing" and while making the fullest possible use of the winding closed on itself under normal working conditions, thus retaining the well known and advantageous load characteristics of the induction motor. In the motors herein described, the commuted winding and the winding closed on itself are preferably placed in the same slots and as near to the air-gap as possible. The winding closed on itself is, therefore, fully effective under normal running conditions and the motor will operate at a nearly constant speed even if the commuted winding be switched out of circuit after the motor has reached its full speed. Since in this improved motor, the mutual induction between the commuted winding and the winding closed on itself is very high, then the latter will be effective in reducing or preventing sparking either at starting or during normal operation. In addition, I make use of the commuted winding for the purpose of improving the power factor and the efficiency of the machine under normal operating conditions.

In the accompanying drawings, which illustrate a motor made in accordance with my invention, and some of the possible modifications thereof, Figs. 1, 2, 3 are diagrammatic views explanatory of the principles of operation of the motor, Fig. 4 shows a simple form of the new motor, Fig. 5 is a phase diagram relating to Fig. 4, and Fig. 6 a graphical representation of the torque conditions obtained in Fig. 4. Fig. 7 is a diagrammatic view of my motor in series connection and making use of a series transformer at starting with means for deriving a compensating voltage from the transformer under running conditions. Fig. 8 shows an arrangement for deriving the compensating voltage from an auxiliary winding on the inducing member, Fig. 9 shows a series arrangement without compensating devices, Fig. 10 shows a series arrangement with means for deriving the compensating voltage from the main inducing winding, Fig. 11 shows a shunt arrangement together with devices for adjusting the phase of the current in the commuted winding, Fig. 12 is a shunt arrangement with means for deriving the starting current and the compensating voltage from the main inducing winding, Fig. 13 is a shunt arrangement wherein the starting current is derived from the main inducing winding, and the compensating voltage from an auxiliary winding disposed on the inducing member, Fig. 14 is an arrangement in which the commuted winding is not only in series, but also in shunt relation to the line at starting, Fig. 15 shows the use of a neutralizing winding closed on itself. Fig. 16 discloses means whereby all the available space and all the copper on the inducing member can be fully utilized under running conditions. Figs. 17 and 18 indicate modified arrangements of brushes on the commutator, and Fig. 19 shows impedances permanently inserted in the circuit of the winding closed on itself.

Like marks of reference refer to similar parts in the several views of the drawings.

Referring to Figs. 1, 2, 3, 4, 5 and 6, 20 represents the main inducing winding supplied from mains 21, and 22 is a winding closed on itself carried on the induced member, here the rotor. It is known that a motor such as shown in Fig. 1 will not start from rest. The reason being that the axis of the only magnetic flux in the motor threading both stator and rotor, coincides with the only current axis in the induced member, both axes fall in the direction Y Y′ in Fig. 1. If the current axis in the induced member can be displaced from the direction Y Y′ for instance, so as to coincide with X X′, while preserving the flux along Y Y′, which flux is due to the winding 20, then a useful torque will be developed. In order to secure this condition I first of all provide the induced member of the machine with an additional winding 23, connected to a commutator in the usual way, and on which rest the brushes 24, as shown in Fig. 3. By means of these brushes I conductively convey through this commuted winding, and along an axis not coinciding with that of the main inducing winding, a current derived from the mains. In Fig. 3 this is achieved by connecting the main inducing winding 20 in series with the commuted winding 23, and the mains 21 by way of the brushes 24. Although a motor constituted as shown in Fig. 3 will start from rest, yet it will develop but a small torque per ampere. The winding 22 which is closed on itself, will now also be acted upon inductively by winding 23. Ampere turns of practically equal magnitude and nearly opposite direction will, therefore, be set up in winding 22, thus effectively neutralizing any torque which winding 23 might otherwise have produced in conjunction with the flux along Y Y′. The torque which sets the motor shown in Fig. 3 in motion, is due to the interaction of the current induced in 22 by 20, with the small flux along X X′ due to the vectorial difference between the ampere turns in 23 and 22 along that axis. In order to secure a larger torque per ampere, I secondly provide a winding 30 disposed on the inducing member, and adapted to produce a magnetization along an axis displaced from that of the main inducing winding 20 by preferably something like $180/n$ degrees, where n stands for the number of poles. This arrangement is shown in Fig. 4. For ease of identification, I will refer to this winding 30 as the "neutralizing winding," for it is designed to control the relation between the ampere turns in 23 and 22 along X X′. This neutralizing winding is to be connected in series relation with the commuted winding either directly or with the interposition of a transformer. The expression "in series relation" is intended throughout the specification and claims to mean that the circuit comprising said neutralizing and commuted windings is so constituted and that those windings are so connected that the current which passes the one always bears a constant ratio to the current passing the other as long as the connections remain unchanged. I have discovered that it is possible to so proportion and dispose this neutralizing winding and to so adjust the phase relation between the currents in 30 and in 23 as to greatly reduce, or even entirely cancel the ampere turns in 22 along X X′. For this purpose it is necessary to take into account the great difference in the leakage conditions existing between 23 and 22 and between 30 and 22, and select the phase, magnitude and space position of the ampere turns in 30 accordingly. This proposition is clearly materially different from that usually met with and where one winding on one member of a machine is to be neutralized by another winding on another member of the machine.

In carrying out my invention and according to the results desired, the stage of the starting performance, the mode of connection, and the constants of the machine, I may cause the neutralizing winding to produce a magnetization, either coinciding in direction, or opposed to that produced by 23, thus either increasing or reducing the ampere turns in 22 along X X′ and as compared with the ampere turns in 23, or reducing them to as near zero as possible, or reversing their sign in respect to those in 23. Assuming that 30 has been so chosen and the phase relation of the currents in 30 and 23 so adjusted as to practically eliminate the ampere turns in 22 along the axis X X′, and that the connections are those shown in Fig. 4, then the operation of my improved motor may be made clear as follows.

If the winding closed on itself has a low ohmic drop as compared with its reactance voltage (or self-induction) then the current i_2, due to e_2 induced therein along Y Y′ by 20 will lag by close on 80 deg. behind e_2 as shown in Fig. 5. Where P is supposed to be the pressure at the terminals of 20, F_y the flux of mutual induction along Y Y′, i_0 the magnetizing current in 20, and i_1 the total current in 20. Since 20 and 23 are connected in series, then the same current i_1 flows through all three windings, and since the winding closed on itself has no ampere turns along X X′, then the ampere turns in 23, due to i_1, can produce a torque with F_y. From Fig. 5 it is seen that the effective torque component ti_1 of i_1 is nearly equal to i_1, the conditions which have been established in accordance with this invention are, therefore, very favorable, and the motor will start with a powerful torque Z_1 due to the interaction of the flux along Y Y′ and of ampere turns on the induced member along X X′. As the speed increases this torque Z_1 diminishes as approximately indicated in Fig. 6. The reason for this is that the phase difference between i_1 and P, as well as the magnitude of i_1 diminish with increasing speed, and that these diminutions are only partly counter-balanced by an increase of F_y; but as the speed increases the winding closed on itself sets up a flux F_x along X X′, which flux is displaced in phase by about 90 deg. with regard to F_y, and the motor then develops another torque Z_2 (see Fig. 6), due to the interaction of F_x with the rotor ampere turns along Y Y′ due to the current i_2 in the winding closed on itself. The resultant torque of the motor is, therefore, Z, and it is seen that it keeps increasing until close to the synchronous speed, which is indicated by the dotted line X, and then rapidly drops to zero. In this manner the motor is automatically converted into an ordinary self-excited shunt induction motor. It has been assumed that the ampere turns in 22 were practically eliminated. This can be fully achieved by adjusting the phase relation between the current passing through 23 and that passing through 30. The means adopted for that purpose in Fig. 4 consist of a resistance 52 connected in parallel to 30. When the motor has reached a sufficient speed switch 53 can be opened thus disconnecting the resistance 52, or the machine may be operated without altering any of the connections. In many cases good results may be secured without adjusting the phase of the current in 23 and 30. In such cases 52 and 53 need not be used and there is no necessity whatsoever to make any changes in the connections after the motor has been connected to the mains, but if refinements are to be introduced, then certain alterations may be made.

When the ampere turns in 22 are to be zero the aim is to so adjust the phase of the current in 23 with relation to that of the current in 30 that the E. M. F. induced in 22 by 23 be exactly opposed in phase to that induced in 22 by 30. When these E. M. F's. are not only of exactly opposite phase but also of equal magnitude, then the ampere turns in 22 along X X′ will be *nil*. This phase relation may be adjusted in any known manner, for instance by connecting an impedance in parallel either to 30 or to 23. When this impedance is to be connected in parallel to 30, then a resistance or a capacity will preferably be used; when it is to be connected in parallel to 23 then a reactance is generally preferable. I may also connect winding 23 in shunt relation to 20, or to the mains 21, instead of in series relation with them. In this case the phase difference between F_y and the current through 23 will, as a rule be greater for otherwise equal conditions, than that between i_1 and F_y in Fig. 5, but the mode of operation will be quite similar. In order to bring the current through 23 more into phase with F_y, I place a reactance or choking coil in the circuit of 23 for the parallel connection, and connect it in parallel to 20 for the series connection. With the help of these explanations it will be readily understood how the improved motor will operate when winding 30 does not entirely eliminate the ampere turns in 22 along X X′. For one thing the reactance of the circuit containing 23 and 30 will be increased in such cases, thus reducing the total current taken by the motor. I, therefore, make use of such an arrangement to reduce the current, taken by the motor when first connected to the mains, to as small an amount as may be desired, gradually allowing the current to increase by changing the number of turns of the neutralizing winding or the direction of the magnetization produced by it, or by both means. In a modification I place the circuit containing the winding 23 both in series and in shunt relation to the mains. I have stated that the neutralizing winding may be in conductive or inductive relation to the commuted winding. The conductive relation can be secured by connecting the two windings in series, either directly or with the interposition of a series transformer. The inductive relation can be secured by short circuiting the neutralizing winding.

Having given the general theoretical idea of the nature of my invention, I will now describe some practical embodiments thereof, and will first refer to Fig. 7, which shows an operative combination with all the switches in the starting position. The mains 21 are connected to the main inducing winding 20 through the primary of the variable ratio series transformer 25. One main 21 is connected to part of the primary of 25 through switch 28 and conductor 27. This primary is connected to 20 through conductor 26. The connection is such that the volts per turn in the main inducing winding can be varied, thus allowing the magnitude of F_y to be regulated even when the terminal voltage is kept constant. The other main 21 is directly connected to 20. An adjustable reactance 34 is connected in parallel to 20 for the purpose of bringing the current in 23 into closer phase coincidence with F_y. The commuted winding 23 is conductively connected to the neutralizing winding 30 by way of one brush 24 and the conductor 49 carrying a movable contact adapted to vary the number of turns in 30. This circuit is fed in series relation with 20 by way of the secondary of the series transformer 25; one end of the secondary of 25 is connected to one of the brushes 24, the other is connected to a point of 30 through the conductor 48, the switch 31 and the conductor 46. The latter carries a movable contact by means of which the transformation ratio of 25 can be varied. An adjustable resistance 52 is connected in parallel to 30 by way of switch 53, for the purpose of adjusting the phase relation between the current through 23 and through 30. The winding 22 closed on itself is shown by way of example as being closed along three axes per pole pair. Another set of brushes disposed along the axis of 20 are in contact with the commuted winding, their circuit is, however, left open at starting. The motor is started by gradually reducing the number of effective turns in 30 to zero, reversing the direction of the magnetization produced by 30, and then increasing the number of effective turns in 30. This is accomplished in Fig. 7 by gradually moving the contact attached to conductor 49 from left to right. When the motor has reached a sufficient speed, the reactance 34 and the resistance 52 are disconnected. The movable contact on conductor 26 is placed in its normal position so as to secure the normal volts per turn in 20. Switch 28 is thrown into contact with conductor 26, whereby the full line voltage is impressed on 20. Switch 31 is thrown into contact with conductor 32, whereby 30 is cut out of circuit. Switch 33 is closed connecting the transformer 25, which did duty as a series transformer at starting, in parallel with the line and the movable contact on conductor 46 is so adjusted as to compensate the motor to the desired extent by means of the voltage derived from the shunt transformer 25 and impressed on the commuted winding 23. Finally switch 51 is closed, thus allowing at least part of the working current to flow through the commuted winding, whereby all the copper on the induced member is utilized to the fullest possible extent.

In Fig. 8 I have shown an operative combination in which the compensation is secured by means of an additional winding 35, disposed on the inducing member coaxially with 20. The winding closed on itself is here shown as being closed along 8 axes per pole pair, and is supposed to be of the form known as the squirrel cage. All switches are shown in the starting position. Winding 30 is adapted to produce a magnetization of opposite direction to that produced by winding 23 and be so adjusted that the squirrel cage carries no current component along the axis of 30. When a sufficient speed has been reached, switch 28 is closed thus short circuiting the primary of the series transformer 25. Switch 31 is opened, thus disconnecting the neutralizing winding and switch 36 is closed, whereby a compensating E. M. F. of suitable phase and magnitude is impressed on 23 from 35 for the purpose of compensating the motor to any desired extent.

In the operative combination shown in Fig. 9, the series transformer is dispensed with. When the motor has reached a sufficient speed, switch 31 is thrown into contact with conductor 32, thus cutting windings 30 and 23 out of circuit, and throwing the full line voltage on 20. When operating the machine in this last named combination, the current taken by the motor passes through the commuted winding along the motor field axis, and lagging a little in phase with respect to the exciting current generated in the winding closed on itself by rotation in the flux F_y it tends to improve the power factor of the motor. In the arrangement shown in Fig. 4, and which has already been discussed, no changes at all are made in the connections after the motor has reached its normal speed.

In the arrangement shown in Fig. 10, the compensating E. M. F. is derived from the main inducing winding 20 by means of connection 37, instead of making use of a separate stator winding, or an outside transformer. When the motor has reached a sufficient speed, winding 30 is cut out of circuit by throwing switch 31 into contact with conductor 29, and the machine is compensated by closing switch 36.

In the operative combination illustrated by Fig. 11, the current conducted through the commuted winding at starting is derived in parallel from the line by means of the shunt transformer 25. The line is directly connected to winding 20, provision being made for varying the volts per turn in this winding. One end of the secondary winding of the shunt transformer 25 is connected to the one brush 24 by means of the conductor 29 carrying a movable contact adapted to vary the ratio of 25; the other end of this secondary is connected to the other brush 24 through switch 31, the adjustable reactance 40, conductor 49, and winding 30. Conductor 49 is provided with a movable contact, by means of which the number of effective turns in 30 can be varied. A reactance 54 is connected in parallel with the commuted winding 23 by way of switch 53 for the purpose of adjusting the phase relation between the current through 23 and the current through 30. When a sufficient speed has been reached, switch 31 is thrown into contact with conductor 32, whereby the reactance and the neutralizing winding are cut out of circuit and switch 53 is opened. The voltage derived from 25 can now be adjusted to secure the desired compensation.

In the arrangement shown in Fig. 12, the shunt transformer 25 of Fig. 11 is combined with the motor itself, the winding 20 thereof being made use of for that purpose. The line is connected directly to part only of winding 20. The circuit including the commuted winding is fed from one terminal of 20 through switch 31, winding 30, impedance 40, brushes 24 to conductor 29, and back to some portion of 20. The movable contact attached to 29 makes it possible to vary the voltage impressed on the circuit comprising the commuted winding, and since the line voltage is only impressed on part of 20, then the voltage impressed on 23 can be raised above the line voltage. When the motor has reached a sufficient speed, switch 31 is thrown into contact with conductor 32, thus disconnecting 30, and the voltage derived from 20 is so adjusted as to secure the desired degree of compensation.

The operative combination shown in Fig. 13 shows an arrangement by means of which a definite voltage, derived from 20 by means of the conductor 29, is impressed at starting on the circuit comprising the commuted winding 23 and the impedance 40 and another voltage, suitable for compensating purposes, is derived from a winding 35 disposed on the stator and impressed on the commuted winding after a sufficient speed has been reached. Under normal working conditions the exciting current flowing through 23 will flow through 35 in a direction opposite to that of the working current flowing through that winding, and as the two are of nearly same phase, 35 will only be called upon to carry their difference. When sufficient speed has been reached, switch 36 is thrown into contact with conductor 32, thus effecting the change described.

Fig. 14 shows one arrangement, the switches standing in the starting position in which the circuit comprising the commuted winding 23 is connected in shunt as well as in series relation to the line. Winding 20 is connected to line 21 through the primary of the variable ratio series auto-transformer 25. The secondary of this transformer is connected in series with 23 by means of conductor 29 and brushes 24, and also in series with 30. The circuit comprising 23 is connected in parallel to the line 21. When a sufficient speed has been reached switch 28 is closed, thus short-circuiting the primary of 25. Switch 31 is thrown into contact with conductor 32, thus cutting 30 out of circuit, and switch 36 is thrown into contact with conductor 46, thus impressing on the commuted winding a suitable compensating voltage derived from 20.

In Fig. 15 is shown one arrangement in which the neutralizing winding is in inductive relation to the commuted winding, and where the commuted winding is not only in series, but also in shunt relation to the line. The main inducing winding 20 and the commuted winding 23 are connected in series across the line 21. An E. M. F. derived from the secondary of the variable ratio shunt transformer 25 connected to the line by the conductors 39, is in addition impressed on 23. At starting, the neutralizing winding 30 is short-circuited by means of switch 31. When a sufficient speed has been reached, switch 31 is opened, and the movable contact attached to conductor is adjusted to secure the desired degree of compensation.

In the examples heretofore described, the neutralizing winding was mostly left out of circuit in normal operation. The space occupied by that winding and the copper used in it were, therefore, wasted.

Fig. 16 shows an operative combination in which all the available winding space and all the copper on the inducing member is fully utilized, while deriving the compensating E. M. F. from a winding disposed on the inducing member. At starting switch 36 is open, when the motor has reached a sufficient speed, winding 30 is left in circuit, and switch 36 is closed. To get the best results it is desirable to dispose the compensating winding 35 along the axis of the resultant flux due to windings 30 and 20 under normal working conditions, and to conduce the current through 23 along an axis displaced by 180/n degrees with respect to the axis of 35. This arrangement, therefore, necessitates a displacement between the axis of 30 and of that of 23, as fixed by the position of the brushes on the commutator. As a result, only part of 23 can be neutralized by 30, and only part of 23 can produce a torque with F_y at starting, the remaining part of 23 either increases or reduces, at starting, the current in the winding closed on itself. In case 23 has many turns as compared with 20, the necessary brush displacement might become inconveniently large; in such case the winding 30 can be divided into several groups of coaxial windings, all groups being connected in series at starting and in parallel when running, by means of switch 60. The space position of 35 must be decided by the parallel grouping of 30, and the full speed conditions.

Instead of disposing the brushes in contact with the commuted winding in the manner shown in Fig. 7, arrangements such as illustrated in Figs. 17 and 18 may be employed. The machine can be started with the brushes connected as shown, or brushes 50 in both figures may be disconnected at starting and connected up as shown when a sufficient speed has been reached. In either figure all the brushes may be shifted for instance through 45 degrees and made use of in this modified position.

Fig. 19 indicates that the winding 22 permanently closed on itself may be so closed over impedances 45 of any kind which can be carried somewhere on the rotor so as to obviate the use of slip rings.

Having fully described my invention, what I claim as new and desire to secure by Letters Patent of the United States is:

1. In an alternating current motor, the combination with an inducing member provided with a main inducing winding, of an induced member provided with a commuted winding and a winding permanently closed on itself, and a neutralizing winding on said inducing member so connected with said commuted winding that the current passing through one will bear a constant ratio to the current passing through the other.

2. In an alternating current motor, the combination with an inducing member provided with a main inducing winding, of an induced member provided with a commuted winding and a winding permanently closed on itself, means for controlling the phase relation between the current in said main inducing winding and said commuted winding, and a neutralizing winding on said inducing member so connected with said commuted winding that the current passing through one will bear a constant ratio to the current passing through the other.

3. In an alternating current motor, the combination with an inducing member provided with a main inducing winding, of an induced member provided with a commuted winding and a winding permanently closed on itself, a neutralizing winding on said inducing member so connected with said commuted winding that the current passing through one will bear a constant ratio to the current passing through the other, and means for varying the ampere turns of the neutralizing winding.

4. In an alternating current motor, the combination with an inducing member provided with a main inducing winding, of an induced member provided with a commuted winding and a winding permanently closed on itself, a neutralizing winding on said inducing member adapted to produce a magnetization displaced in space from that due to the said main inducing winding, means for compensating the motor after starting, and means for conducting through said commuted winding a current derived from the line.

5. In an alternating current motor the combination with an inducing member provided with a main inducing winding, of an induced member provided with a commuted winding and a winding permanently closed on itself, a neutralizing winding on said inducing member in series relation with said commuted winding and arranged to oppose the magnetization produced by said commuted winding, and means for conducting through said commuted winding a current derived from the line.

6. In an alternating current motor, the combination with an inducing member provided with a main inducing winding, of an induced member provided with a commuted winding and a winding permanently closed on itself, a neutralizing winding on said inducing member in series relation with said commuted winding and arranged to oppose the magnetization produced by said commuted winding, means for varying the ampere turns of said neutralizing winding, and means for conducting through said commuted winding a current derived from the line.

7. In an alternating current motor, the combination with an inducing member provided with a main inducing winding, of an induced member provided with a commuted winding and a winding permanently closed on itself, a neutralizing winding on said inducing member adapted to produce a magnetization displaced in space from that due to the main inducing winding, means for conducting through the commuted winding a current derived from the mains and

means for cutting the neutralizing winding out of circuit after the motor has started.

8. In an alternating current motor, the combination with an inducing member provided with a main inducing winding, of an induced member provided with a commuted winding and a winding permanently closed on itself, a neutralizing winding on said inducing member so connected with said commuted winding that the current passing through one will bear a constant ratio to the current passing through the other, and means for varying the volts per turn in said main inducing winding.

9. In an alternating current motor, the combination with an inducing member provided with a main inducing winding, of an induced member provided with a commuted winding and a winding permanently closed on itself, a neutralizing winding on said inducing member so connected with said commuted winding that the current passing through one will bear a constant ratio to the current passing through the other, and means for controlling the phase relation between the current in said commuted winding and the current in said neutralizing winding.

10. In an alternating current motor, the combination with an inducing member provided with a main inducing winding, of an induced member provided with a commuted winding and a winding permanently closed on itself, means for controlling the phase relation between the current in said main inducing winding and said commuted winding, a neutralizing winding on said inducing member adapted to produce a magnetization displaced in space from that due to the said main inducing winding, means for controlling the phase relation between the current in said commuted winding and the current in said neutralizing winding, and means for conducting through said commuted winding a current derived from the line.

11. In an alternating current motor, the combination with an inducing member provided with a main inducing winding, of an induced member provided with a commuted winding and a winding permanently closed on itself, a neutralizing winding on said inducing member adapted to produce a magnetization displaced in space from that due to the said main inducing winding, means for controlling the phase relation between the current in said commuted winding and the current in said neutralizing winding, means for compensating the motor after starting, and means for conducting through said commuted winding a current derived from the line.

12. In an alternating current motor, the combination with an inducing member provided with a main inducing winding, of an induced member provided with a commuted winding and a winding permanently closed on itself, a neutralizing winding on said inducing member adapted to produce a magnetization displaced in space from that due to the main inducing winding, means for conducting through the commuted winding the current derived from the line, and means for short-circuiting the said commuted winding along an axis approximately coinciding with that of the main inducing winding.

13. In an alternating current motor, the combination with an inducing member provided with a main inducing winding, of an induced member provided with a commuted winding and a winding permanently closed on itself, said commuted winding being connected in series relation with said inducing winding, and means for compensating the motor.

14. In an alternating current motor, the combination with an inducing member provided with a main inducing winding, of an induced member provided with a commuted winding and a winding permanently closed on itself, said commuted winding being connected in series relation with said main inducing winding, means for controlling the phase relation between the current in said main winding and commuted winding for increasing the torque, and means for compensating the motor.

15. In an alternating current motor, the combination with an inducing member provided with a main inducing winding, of an induced member provided with a commuted winding and a winding permanently closed on itself, a series transformer interposed between said main inducing winding and said commuted winding, and means for impressing on said commuted winding, after the motor has started, an E. M. F. derived from said transformer in order to compensate the motor.

16. In an alternating current motor, the combination with an inducing member provided with a main inducing winding, of an induced member provided with a commuted winding and a winding permanently closed on itself, a neutralizing winding on said inducing member arranged to oppose the magnetization produced by said commuted winding and means for compensating the motor.

17. In an alternating current motor, the combination with an inducing member provided with a main inducing winding, of an induced member provided with a commuted winding and a winding permanently closed on itself, said commuted winding being in series relation with said main inducing winding at starting, a neutralizing winding on said inducing member arranged to produce a magnetization substantially along the same axis as that produced by said commuted winding, and means for impressing a com-

pensating E. M. F. on the commuted winding after starting.

18. In an alternating current motor, the combination with an inducing member provided with a main inducing winding, of an induced member provided with a commuted winding and a winding permanently closed on itself, a neutralizing winding on said inducing member arranged to produce a magnetization substantially along the same axis as that produced by said commuted winding, a series transformer interposed between said inducing member and said commuted winding at starting, and means for impressing on said commuted winding after starting a compensating E. M. F. derived from said transformer.

19. In an alternating current motor, the combination with an inducing member provided with a main inducing winding, of an induced member provided with a commuted winding and a winding permanently closed on itself, said commuted winding being in series relation with said main inducing winding at starting a neutralizing winding on said inducing member arranged to produce a magnetization substantially along the same axis as that produced by said commuted winding, and means for cutting said neutralizing winding out of circuit after starting.

20. In an alternating current motor, the combination with an inducing member provided with a main inducing winding, of an induced member provided with a commuted winding and a winding permanently closed on itself, a series transformer interposed between said main inducing winding and the commuted winding, a neutralizing winding on said inducing member arranged to produce a magnetization substantially along the same axis as that produced by said commuted winding, and means for impressing on said commuted winding after starting a compensating E. M. F. derived from said transformer.

21. In an alternating current motor, the combination with an inducing member provided with a main inducing winding, of an induced member provided with a commuted winding and a winding permanently closed on itself, means for controlling the phase relation between the current in said main inducing winding and in said commuted winding for the purpose of increasing the torque, a series transformer interposed between said main inducing winding and the commuted winding, a neutralizing winding on said inducing member arranged to produce a magnetization displaced in space from that due to the main inducing winding, and means for impressing on said commuted winding after starting a compensating E. M. F. derived from said transformer.

22. In an alternating current motor, the combination with an inducing member provided with a main inducing winding, of an induced member provided with a commuted winding and a winding permanently closed on itself, means for controlling the phase relation between the current in said main inducing winding and commuted winding for increasing the torque, a series transformer interposed between said inducing member and commuted winding, a neutralizing winding on said inducing member arranged to produce a magnetization displaced from that due to the said main inducing winding, means for cutting said neutralizing winding out of circuit after the motor has started, and means for impressing on said commuted winding after starting a compensating E. M. F. derived from said transformer.

23. In an alternating current motor, the combination with an inducing member provided with a main inducing winding, of an induced member provided with a commuted winding and a winding permanently closed on itself, means for controlling the phase relation between the current in said main inducing winding and commuted winding for increasing the torque, a transformer interposed between said main inducing winding and commuted winding, a neutralizing winding on said inducing member arranged to produce a magnetization displaced from that due to the main inducing winding, means for cutting said neutralizing winding out of circuit, means for impressing on said commuted winding after starting a compensating E. M. F. derived from said transformer, and means for varying the magnitude of said compensating E. M. F.

24. In an alternating current motor, the combination with an inducing member provided with a main inducing winding, of an induced member provided with a commuted winding and a winding permanently closed on itself, means for controlling the phase relation between the current in said main inducing winding and commuted winding for increasing the torque, a transformer interposed between said main inducing winding and commuted winding, a neutralizing winding on said inducing member adapted to produce a magnetization displaced by 180/n degrees from that due to the main inducing winding, means for cutting said neutralizing winding out of circuit, means for impressing on said commuted winding after starting a compensating E. M. F. derived from said transformer, and means for varying the magnitude of said compensating E. M. F.

25. In an alternating current motor, the combination with an inducing member provided with a main inducing winding, of an induced member provided with a commuted winding and a winding permanently closed on itself, means for controlling the phase

relation between the current in said main inducing winding and commuted winding for increasing the torque, a transformer interposed between said main inducing winding and commuted winding, a neutralizing winding on said inducing member adapted to produce a magnetization displaced by 180/n degrees from that due to the main inducing winding, means for controlling the phase relation between the current in said commuted winding and the current in said neutralizing winding, means for cutting said neutralizing winding out of circuit, means for impressing on said commuted winding after starting a compensating E. M. F. derived from said transformer, and means for varying the magnitude of said compensating E. M. F.

26. In an alternating current motor the combination with an inducing member provided with a main inducing winding, of an induced member provided with a commuted winding and a winding permanently closed on itself, means for controlling the phase relation between the current in said main inducing winding and commuted winding for increasing the torque, a transformer interposed between said main inducing winding and commuted winding, a neutralizing winding on said inducing member adapted to produce a magnetization displaced by 180/n degrees from that due to the main inducing winding, means for cutting said neutralizing winding out of circuit, means for impressing on said commuted winding after starting a compensating E. M. F. derived from said transformer, means for varying the magnitude of said compensating E. M. F., and means for short-circuiting said commuted winding along an axis approximately coinciding with that of the main inducing winding.

27. In an alternating current motor, the combination with an inducing member provided with a main inducing winding, of an induced member provided with a commuted winding and a winding permanently closed on itself, a neutralizing winding on said inducing member adapted to produce a magnetization displaced in space by 180/n degrees from that due to the main inducing winding, means for conducting through said commuted winding, along an axis coinciding with that of the neutralizing winding, a current derived from the line, means for cutting the neutralizing winding out of circuit, and means for impressing a compensating E. M. F. on the commuted winding after the motor has reached a sufficient speed.

28. In an alternating current motor, the combination with an inducing member provided with a main inducing winding, of an induced member provided with a commuted winding and a winding permanently closed on itself, a neutralizing winding on said inducing member adapted to produce a magnetization displaced in space by 180/n degrees from that due to the main inducing winding, means for conducting through said commuted winding, along an axis coinciding with that of the said neutralizing winding, a current derived from the line, and of means for impressing a compensating E. M. F. on the commuted winding after the motor has reached a sufficient speed.

29. In an alternating current motor, the combination with an inducing member provided with a main inducing winding, of an induced member provided with a commuted winding and a winding permanently closed on itself, a neutralizing winding on said inducing member adapted to produce a magnetization displaced in space by 180/n degrees from that due to the main inducing winding, means for conducting through said commuted winding along an axis coinciding with that of the said neutralizing winding, a current derived from the line, and means for cutting the neutralizing winding out of circuit after the motor has reached a sufficient speed.

In testimony whereof I have hereunto set my hand and affixed my seal in the presence of the two subscribing witnesses.

VALÈRE ALFRED FYNN. [L. S.]

Witnesses:

E. E. HUFFMAN,

W. A. ALEXANDER.