No. 735,686. PATENTED AUG. 4, 1903.

A. P. ZANI.

METHOD OF OPERATING ALTERNATING CURRENT INDUCTION MOTORS.

APPLICATION FILED APR. 30, 1902.

NO MODEL.

FIG. 1.

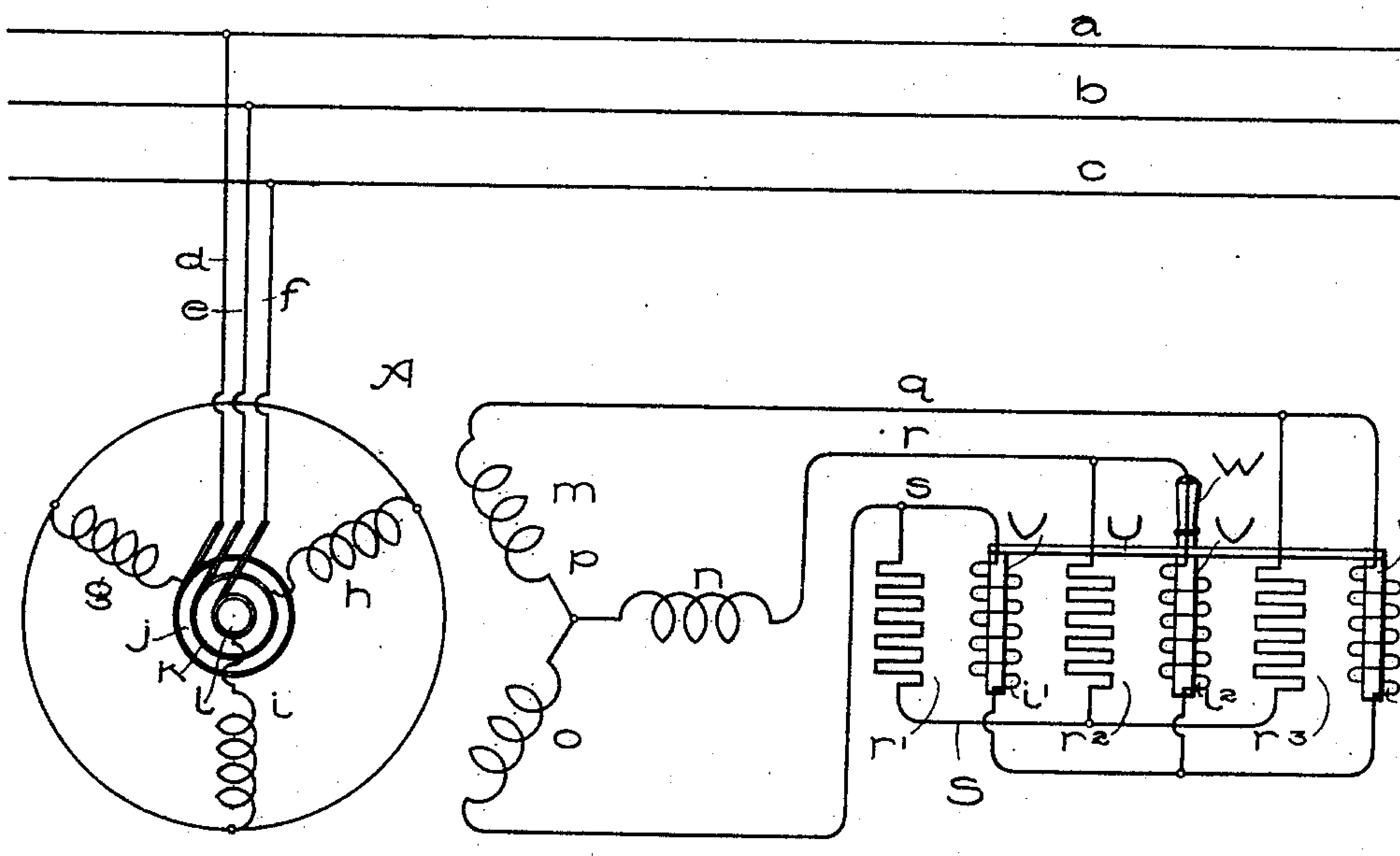


FIG. 2.

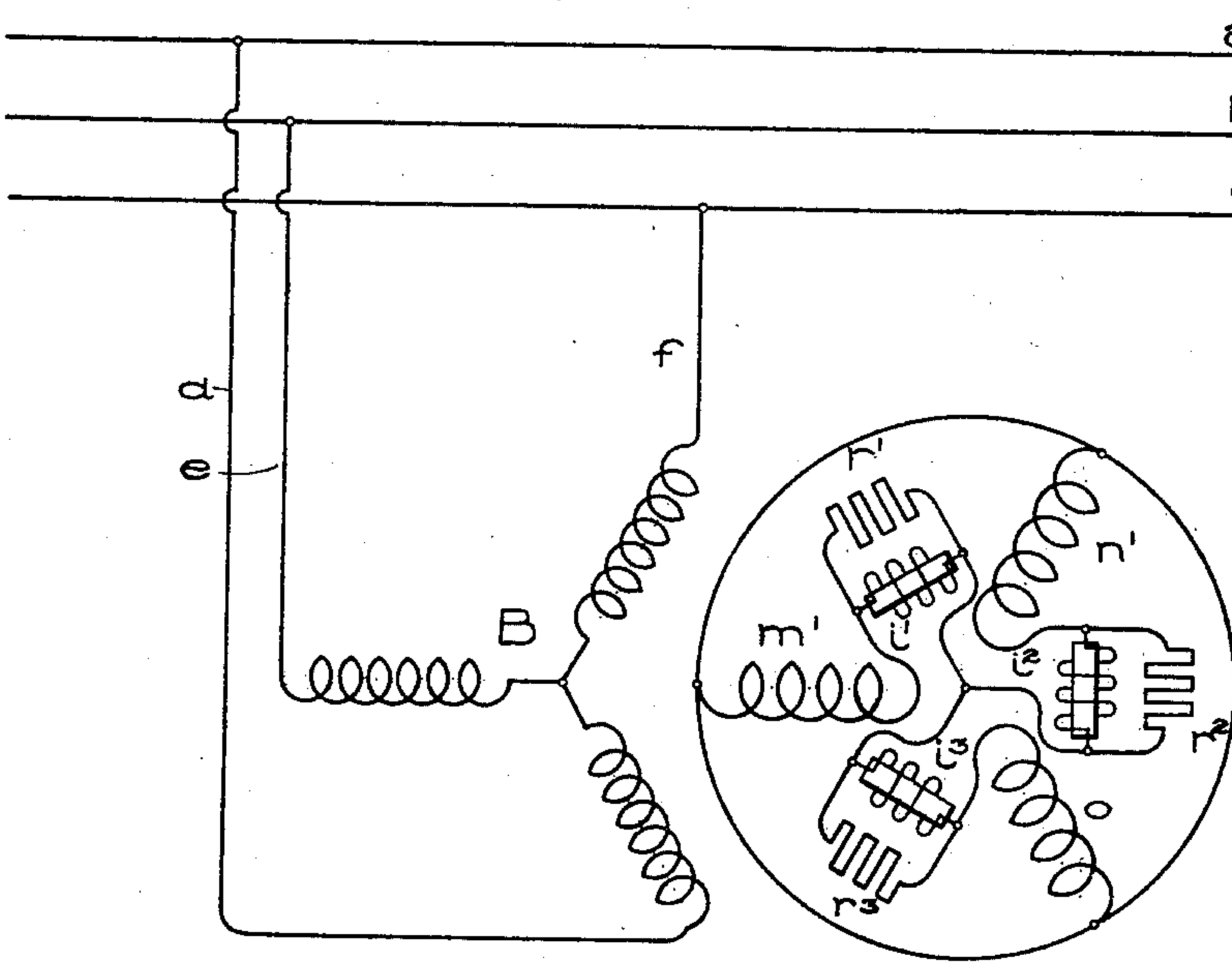
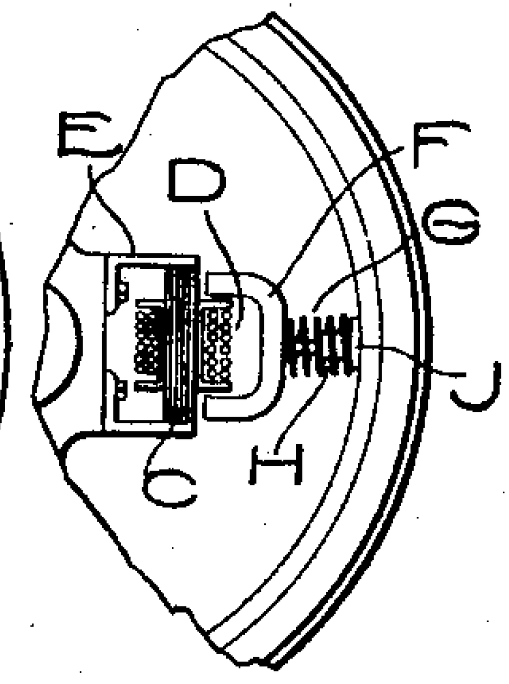


FIG. 3.



WITNESSES

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Att'y.

No. 735,686. Patented August 4, 1903.

UNITED STATES PATENT OFFICE.

ARNALDO P. ZANI, OF BERLIN, GERMANY, ASSIGNOR TO GENERAL ELECTRIC COMPANY, A CORPORATION OF NEW YORK.

METHOD OF OPERATING ALTERNATING-CURRENT INDUCTION-MOTORS.

SPECIFICATION forming part of Letters Patent No. 735,686, dated August 4, 1903.

Original application filed August 11, 1899, Serial No. 726,910. Divided and this application filed April 30, 1902. Serial No. 105,310. (No specimens.)

To all whom it may concern:

Be it known that I, ARNALDO P. ZANI, a subject of the King of Italy, residing at Berlin, Germany, have invented certain new and useful Improvements in Methods of Operating Alternating-Current Induction-Motors, of which the following is a specification.

This case is a division of my application, Serial No. 726,910, filed August 11, 1899.

In starting induction-motors a non-inductive resistance is commonly inserted in circuit with the windings on the induced member of the motor in order to increase the starting torque and at the same time reduce the amount of current supplied to the motor. The resistance has the effect of bringing the currents in the induced member of the motor more nearly into phase with the electromotive forces induced therein and at the same time by reducing the amount of secondary current causes a more than correspondingly large reduction in the primary current. This reduction in the primary current is largely due to the fact that a reduced secondary current reduces the leakage-flux between the inducing and induced members of the motor, and consequently reduces the amount of lagging or idle current called for by the self-induction produced by this leakage-flux. A further description of the function of the starting resistance is unnecessary, since its operation is well understood by engineers.

In practice the non-inductive resistance may be operatively connected to the windings of the induced member in a number of different ways. Thus, for example, if the rotor be the induced member the resistance may be carried by the spider of the rotor or may otherwise be mounted within the same, or, if desired, the resistance may be located externally to the motor and connected to the windings of the induced member through collector-rings on the rotor-shaft. If the resistance is mounted within the rotor, it may be cut in or out by means of centrifugally-actuated switches carried by the rotor or by means of switches mounted on the rotor and connected by suitable mechanical devices with a switch-handle fulcrumed to some portion of the stator in a manner well known in the art. In cases where the resistance is externally located the same may be varied in value by any well-known means. In any case, however, these constructions are seldom absolutely sparkless in operation and are open to all the other objectionable features inherent in sliding contacts. In most cases the sparking produced at the contacts is not of sufficient importance to become seriously objectionable, while in some cases it is, on the contrary, so dangerous as to be prohibitive—as, for instance, where the motors or other devices are to be used in an atmosphere of an explosive nature such as exists in flouring-mills, oil-refineries, or the like. I have therefore devised a novel method for starting induction-motors which possesses the advantages of the well-known rheostatic form of control, though acting on a different principle, without its corresponding disadvantages. According to my invention the currents in the induced member of the induction-motor are caused to flow through a circuit provided with alternative paths, one of high ohmic resistance and little if any self-induction, the other of low resistance, but of comparatively high self-induction. At starting, when the frequency of the currents in the induced member is high, the reactance in the path of high induction is so large as practically to prevent any considerable current from flowing in this path, thus causing nearly all of the current generated in the induced member to pass through the high-resistance path. The result obtained is nearly the same as though the high-resistance path were the only one presented to the induced currents of the induced member. As the speed of the machine rises, however, the frequency of the currents in the induced member becomes less and less, thus correspondingly decreasing the reactance due to self-induction, and so causing a greater portion of the induced current to pass through the self-inductive path and less through the path of high resistance. When the speed of the motor has risen sufficiently, the frequency of current in the induced member becomes so low that the counter electromotive force of self-induction in the inductive path is greatly reduced. Then nearly all of the current will flow through this path, which is of low resistance, and only a small amount through the other path of high resistance. This operation preserves the proper phase relation between current and electromotive force at all speeds without any mechanical adjustment whatever, though, if desired, I may still further vary the amount of reactance due to the inductive path before mentioned not by depending upon a decrease in frequency of currents flowing in said path, but by varying the coefficient of self-induction of the inductive device in any desired manner—as, for instance, by varying the reluctance of its magnetic circuit.

The amount of energy consumed in the circuit connected to the winding of the induced member of the motor will be greater the greater the portion of the induced current which is caused to flow through the high-resistance path or branch of said circuit. The consumption of energy in this circuit is measured by the product of the square of the current flowing in the circuit and what I have termed the "effective resistance" of the circuit, meaning thereby the equivalent resistance which in a circuit having a single path would consume a similar amount of energy. This effective resistance changes, of course, with any change in the inductance of the inductive circuit, and since the inductance is directly proportional to the frequency of the current in the induced member of the motor the effective resistance of the circuit decreases as the frequency of the currents in the induced member of the motor decreases or as the speed of the motor increases. As already explained, the inductance of the inductive path may be still further reduced by so constructing and connecting the core of the inductive device that the reluctance of the magnetic circuit of said device, and therefore its coefficient of self-induction, will be reduced as the motor rises in speed.

My invention will be better understood and the details of the apparatus by means of which it may be carried out more clearly apprehended by reference to the following description, taken in connection with the accompanying drawings, while its scope will be clearly and particularly pointed out in the appended claims.

Figure 1 represents one arrangement for carrying out my invention as applied to an induction-motor in which the induced member is stationary. Fig. 2 shows a similar arrangement in connection with a motor having a revolving induced member. Fig. 3 illustrates a detail of the apparatus.

In Fig. 1, *a b c* represent three-phase supply-mains, which are connected through leads *d e f* with the windings *g h i* of the inducing member of an induction-motor A. The inducing member is here shown as a rotor, and the connections between the leads *d e f* and the rotor-windings are therefore made by means of collector-rings *j k l* and suitable brushes operating in connection therewith, as is well understood. The stationary induced member is provided with windings *m n o*, with one end of each winding connected to a common point *p*, while the free ends of the windings are connected through leads *q*, *r*, and *s* with a set of resistances and inductances in shunt to each other. To be more explicit, the resistances referred to are indicated at r' r^2 r^3, one end of each resistance being connected to a common point in any suitable manner—as, for instance, by means of the conductor S. The free ends of the resistances are connected, respectively, with the leads *s r q*. In an exactly similar manner three inductance devices i' i^2 i^3 are provided, with one end of the circuit of each device connected, respectively, to the leads *s r q* and the other ends connected together electrically, as shown. The inductance devices may consist of solenoids with cores of magnetic material, which may be moved in or out of the solenoids in order to vary the reluctance of the magnetic circuits of the same, and thus vary the coefficient of self-induction. As indicated in the diagram, the cores V are mounted on the cross-bar U, to which a handle W or other operating device is suitably connected, so as to simultaneously move the cores in and out of the solenoids.

Fig. 2 shows a slightly-different arrangement of apparatus for carrying out my invention, such as becomes necessary when the rotor of the induction-motor is used as the induced member. In this case *a b c* indicate, as before, the three-phase supply-mains, while *d e f* denote the leads, through which connections are made between the supply-mains and the windings of the inducing member B of the induction-motor. The induced member is here shown diagrammatically with the resistances r' r^2 r^3 in circuit, respectively, with the windings m' n' o'. Inductance devices i' i^2 i^3 are placed in shunt to the resistances, thus forming with the same divided circuits which are traversed by the currents set up in the induced windings. As heretofore explained, the proportion in which the currents divide between the inductive and the non-inductive paths depends upon the amount of reactance set up in the inductive path. At starting the reactance is high owing to the high frequency of the currents flowing in the induced winding, while at or near normal speed the frequency becomes so small as to make the reactance almost negligible, in which case but little current flows through the path of high resistance, the greater portion of it having been diverted to the low-resistance alternative path, the reactance of which is very low when the motor approaches normal speed.

When it is desired to still further decrease the reactance of the inductance devices i' i^2 i^3 by opening their magnetic circuits as the motor approaches normal speed, I make use of a centrifugally-actuated device. (Illustrated in

Fig. 3.) The inductance device, such as shown in this figure, consists of a core C, of magnetic material, having placed thereon a suitable winding or solenoid D. The core C is supported by brackets E, of non-magnetic material, and its magnetic circuit is completed by means of a yoke F, the ends of which are arranged in proximity to the ends of the core C. The yoke F is arranged in any suitable manner, so as to be movable radially by the action of centrifugal force away from the core C, while the spring G or other suitable means is employed for urging the yoke toward the core C. As here shown, the yoke F is provided with a shank H, arranged to slide in a suitable bearing J, carried by the rotor. When the motor approaches normal speed, the yoke F is moved away from the core C by the action of centrifugal force, and the air-gaps thus introduced into the magnetic circuit of the inductance devices are such as to make the self-induction negligible.

While the apparatus which I have illustrated herein is adapted for use in connection with a three-phase induction-motor, it will of course be understood that my invention is in no sense limited to this particular type of motor, but is equally applicable to other types of induction-motors, whether single phase or multiphase. It will also be understood that my invention may be used in other connections than with induction-motors where it is desired to vary the effective resistance of a circuit through which an alternating current is caused to flow.

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

1. The method of varying the amount of energy consumed in a circuit, which consists in causing the current in said circuit to divide, opposing one portion of said current by ohmic resistance, opposing another portion of the current by reactance, and varying the frequency of said currents.

2. The method of varying the effective resistance of an electric circuit, which consists in causing the current in said circuit to divide, opposing one portion of said current by an ohmic resistance, opposing another portion of said current by an electromotive force proportional to the frequency of said current, and varying the frequency of said currents.

3. The method of operating an alternating-current motor, which consists in causing current in a winding on the motor to divide, passing one portion of said current through a path of high resistance, passing another portion through a path possessing inductance, and varying the value of said inductance.

4. The method of operating an alternating-current motor, which consists in causing current in a winding on said motor to divide, passing one portion of said current through a path of high resistance, passing another portion through a path possessing reactance but of low resistance, and varying the value of such reactance.

5. The method of operating an alternating-current motor, which consists in causing current in a winding on said motor to divide, passing one portion of said current through a path of high resistance, passing another portion through a path possessing reactance, and varying the value of said reactance.

6. The method of operating an induction-motor, which consists in causing current in a winding on the induced member of the motor to divide, and varying the ratio of the divided currents.

7. The method of operating an alternating-current motor, which consists in causing current in a winding on said motor to divide, passing one portion of said current through a path of high resistance, passing another portion through a path possessing reactance but of low resistance, and varying the frequency of said currents.

8. The method of operating induction-motors, which consists in passing current from the induced member through a divided circuit having branches of different power factor.

9. The method of operating induction-motors, which consists in passing current from the induced member through a divided circuit having branches of different power factor, and varying the ratio between the power factors.

10. The method of operating induction-motors, which consists in passing current from the induced member through a divided circuit having branches of different power factor, and varying the frequency of said current.

11. The method of varying the energy consumed in the circuit of the induced member of an induction-motor, which consists in providing two paths for the current, one of high resistance and the other of low resistance, opposing the flow of current through the path of low resistance, and varying the amount of such opposition.

12. The method of varying the effective resistance in circuit with the induced member of an alternating-current motor, which consists in passing part of the current in the induced member through a path of high resistance and another part through a path possessing reactance but of low resistance.

13. The method of varying the effective resistance in circuit with the windings of the induced member of an induction-motor, which consists in passing the current in said windings through divided paths of different resistance, and varying the relative division of currents between the different branches of said paths.

14. The method of operating an alternating-current induction-motor, which consists in magnetizing the primary member of the motor by current from an alternating source, generating current in the secondary member of said motor by induction from the primary member, and causing said current to flow

through a circuit so organized that at starting it will have the effect of a circuit containing a high ohmic resistance and at full speed the effect of a circuit containing a low ohmic resistance.

15. The method of starting an alternating-current induction-motor, which consists in magnetizing the primary member by current from an alternating source, generating current in the secondary member of said motor by induction from the primary member, and causing said current to flow through a low-resistance circuit so organized that at low speeds when the frequency of the currents flowing in the secondary member is high it will have the effect of a circuit containing a high ohmic resistance.

In witness whereof I have hereunto set my hand this 16th day of April, 1902.

ARNALDO P. ZANI.

Witnesses:

FRANCIS W. FRIGOUT,
ALFRED NUTTING.