No. 755,829. PATENTED MAR. 29, 1904.

A. P. ZANI.

CONTROLLING INDUCTION MOTORS.

APPLICATION FILED JUNE 30, 1900.

NO MODEL. 2 SHEETS—SHEET 1.

Fig. 1.

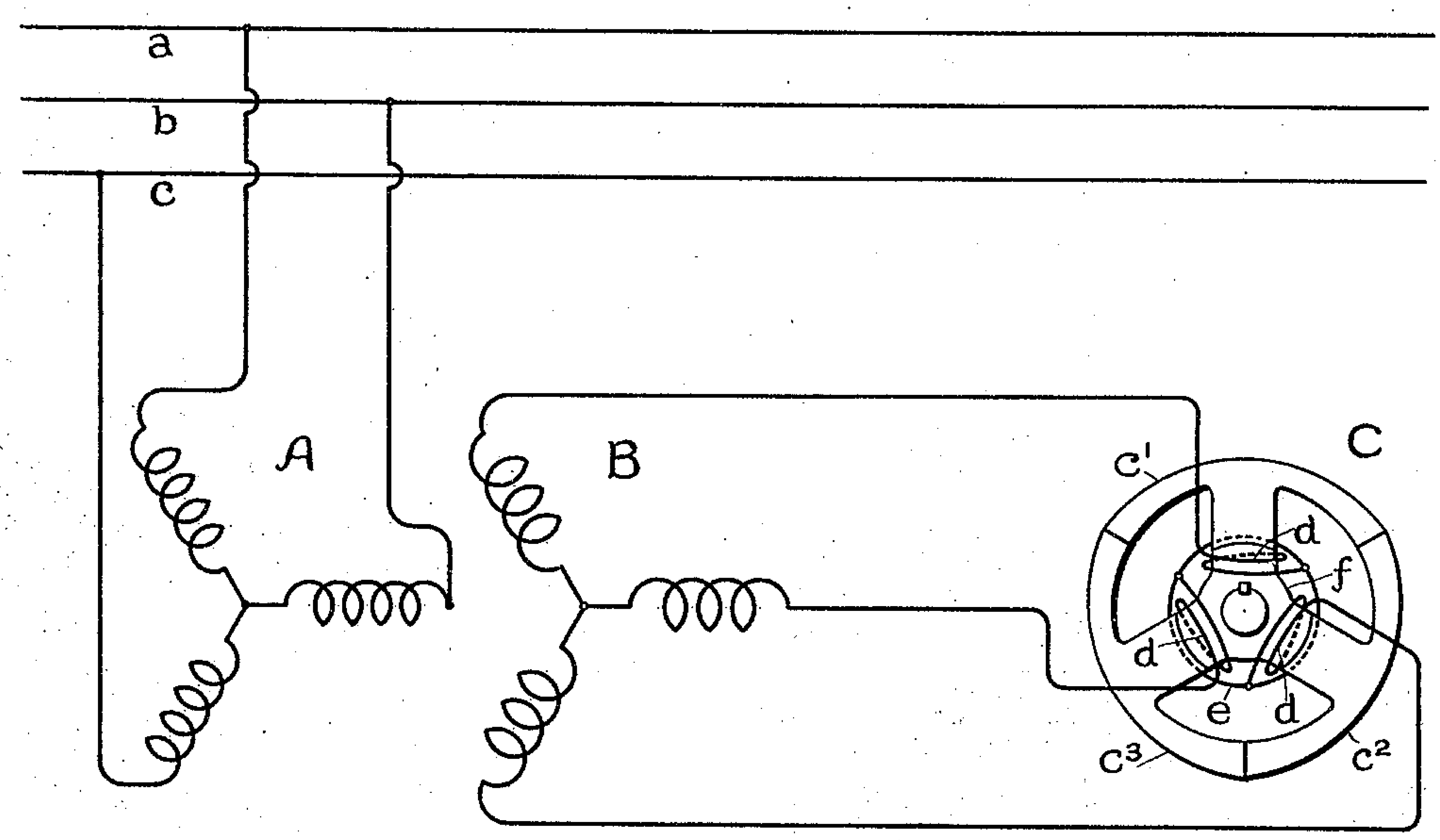


Fig. 2.

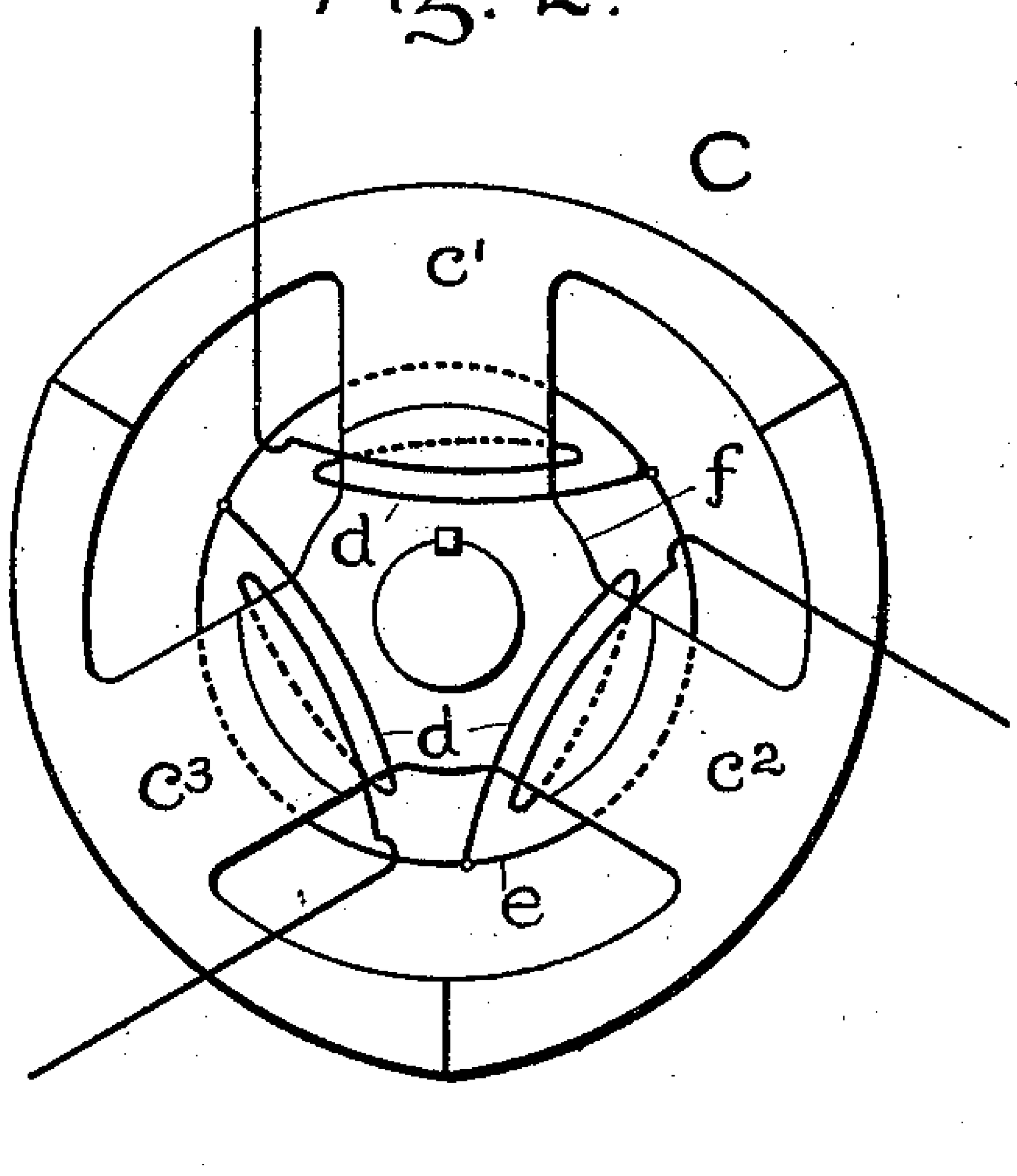
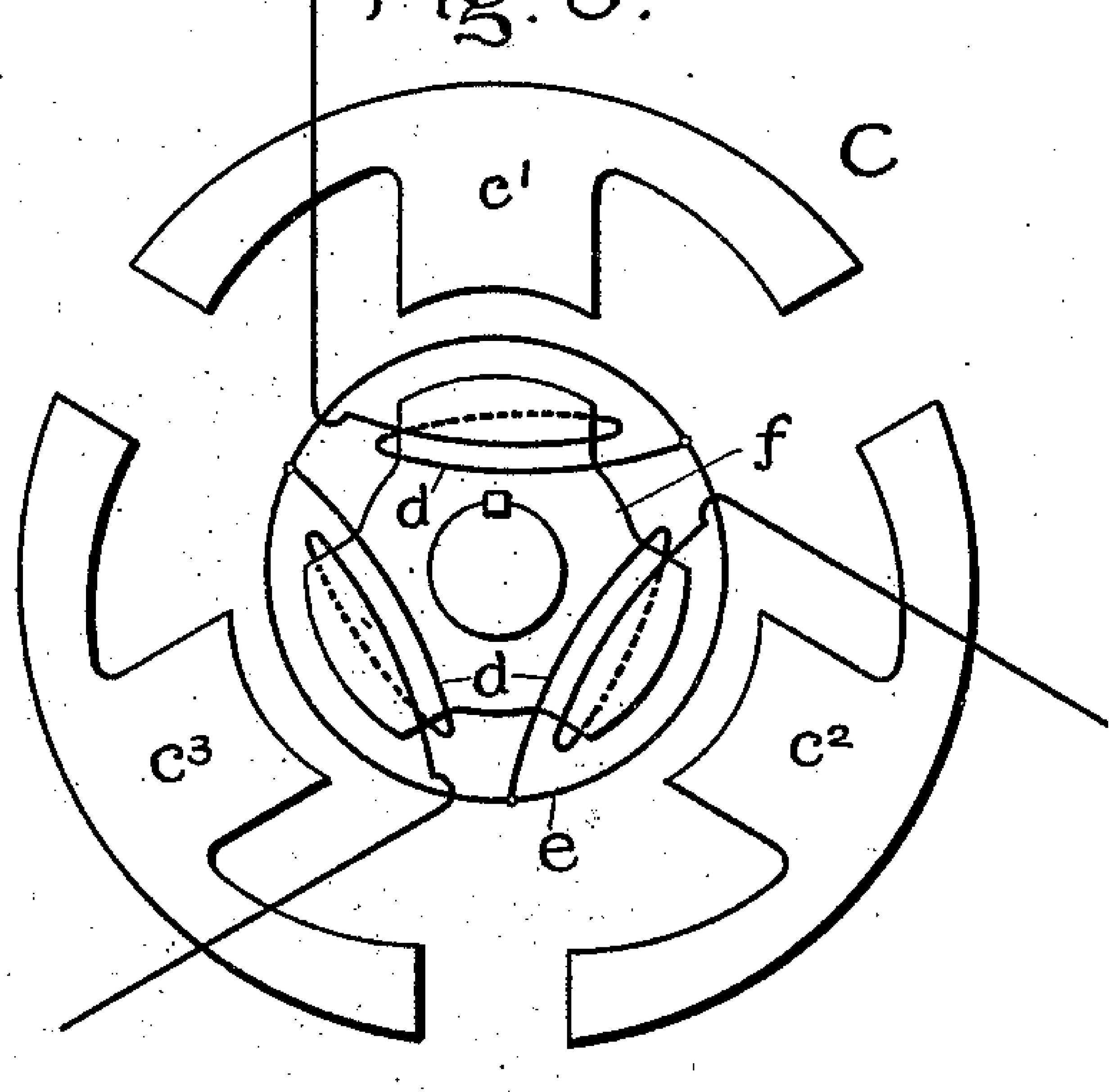


Fig. 3.



Witnesses:

Lewis E. Abell.

Benjamin B. Hull.

Inventor.

Arnaldo P. Zani,

by Albert G. Davis

Atty.

THE NORRIS PETERS CO., PHOTO-LITHO., WASHINGTON, D. C.

No. 755,829. PATENTED MAR. 29, 1904.

A. P. ZANI.

CONTROLLING INDUCTION MOTORS.

APPLICATION FILED JUNE 30, 1900.

NO MODEL. 2 SHEETS—SHEET 2.

Fig. 4.

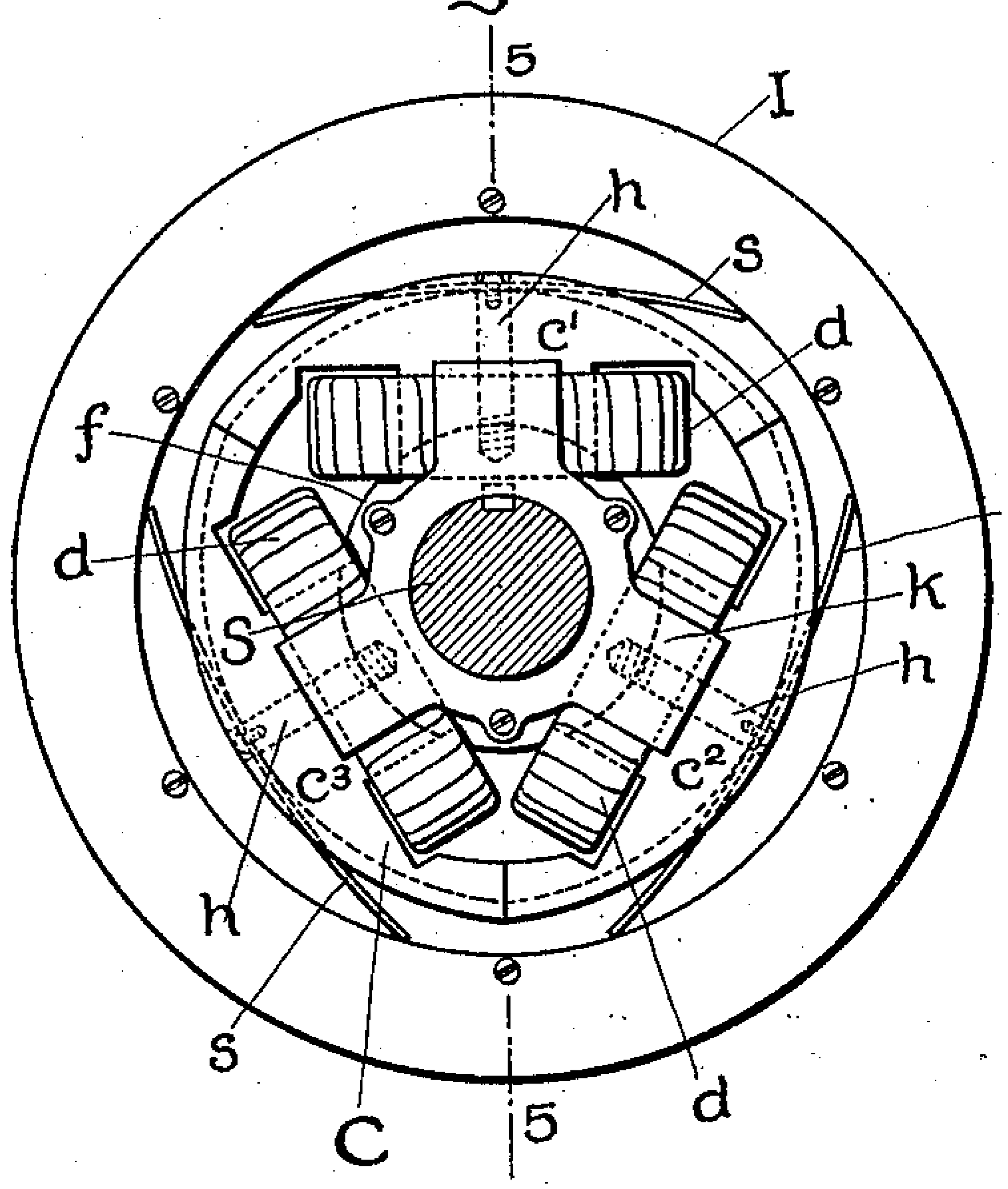


Fig. 5.

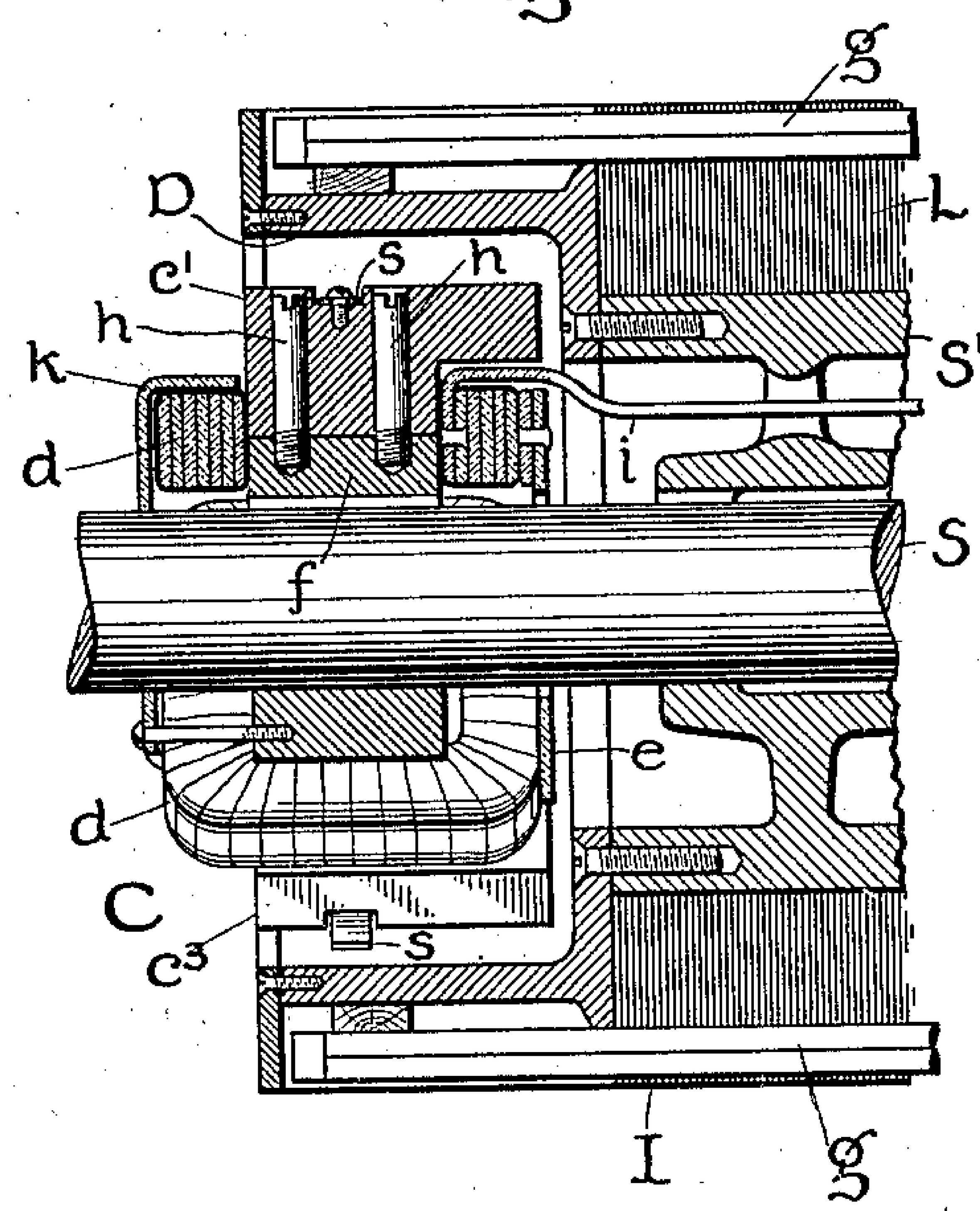
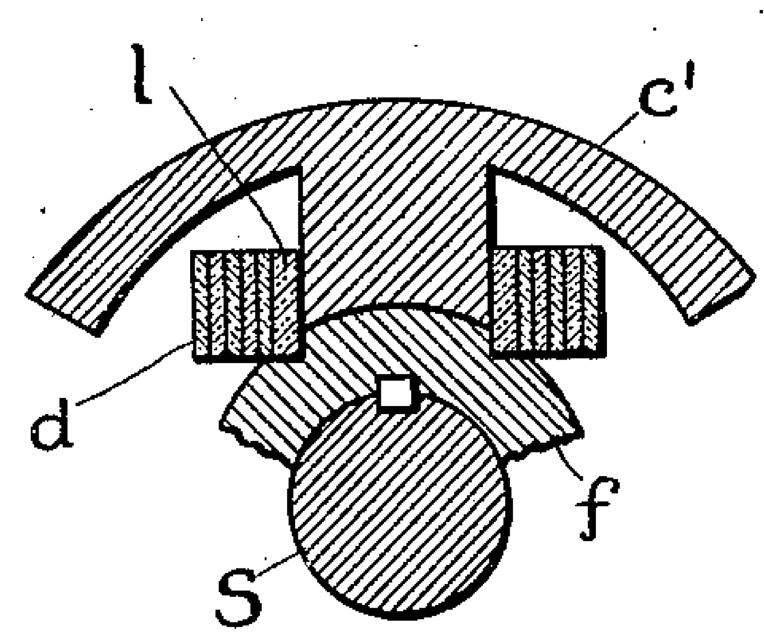


Fig. 6.



Witnesses:

Lewis E. Abell.

Benjamin B. Hull.

Inventor.

Arnaldo P. Zani,

by Albert G. Davis

Atty.

No. 755,829. Patented March 29, 1904.

UNITED STATES PATENT OFFICE.

ARNALDO P. ZANI, OF MILAN, ITALY, ASSIGNOR TO GENERAL ELECTRIC COMPANY, A CORPORATION OF NEW YORK.

CONTROLLING INDUCTION-MOTORS.

SPECIFICATION forming part of Letters Patent No. 755,829, dated March 29, 1904.

Application filed June 30, 1900. Serial No. 22,139. (No model.)

To all whom it may concern:

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

My invention relates to an arrangement for starting induction-motors, and constitutes an improvement over the arrangement disclosed in my prior application, filed August 11, 1899, Serial No. 726,910. In said prior arrangement the current induced in the secondary member of the motor was caused to flow through a circuit so organized that in starting there would be a large consumption of energy in the form of resistance loss, the current lagging somewhat, due to the inductance of the said circuit, while as the motor increased in speed the effective resistance, as well as the inductance of the circuit, would be automatically decreased without change in the actual circuit connections. In the arrangement disclosed in my prior application the circuit for the induced member was provided with alternative paths, one of such paths having a high ohmic resistance and little, if any, self-induction and the other having an almost negligible resistance, but a comparatively high self-induction. In starting a motor with such an arrangement a large proportion of the current generated in the induced member will at first flow through the high-resistance path, for the reason that at the time of starting the reactance of the path having the high self-induction is very great, (due to the high frequency of the currents generated in the induced member at this time.) The result obtained at starting is therefore nearly the same as though the high-resistance path were the only one connected to the winding of the induced member. As the speed of the motor rises, however, the frequency of the currents flowing in the induced windings of the motor becomes lower and lower, thus correspondingly reducing the reactance due to self-induction in the inductive path, and more and more current flows through this path until, finally, when the speed of the motor approaches normal the impedance of the inductive path becomes so small (due to the fact that the frequency of the currents flowing in the induced member is now very low) that nearly all the current generated will flow through the low-resistance inductive path. If desirable, I may as the motor approaches full speed still further reduce the reactance of the inductive path by reducing its coefficient of self-induction in any suitable manner, as by increasing the reluctance of its magnetic circuit.

By the arrangement above described I have been enabled to obtain without changing the circuit connections of the secondary member of an induction-motor and without changing the actual resistance in circuit therewith a large resistance loss at starting, while at full speed the resistance loss is very small, so that by this construction I have been enabled to start an induction-motor with a large torque and without excessive current consumption. I have now found that I may obtain substantially the same results with but a single path in the circuit of the induced or secondary member. In my new arrangement I so organize this single path that it will combine the effects of the inductive and non-inductive paths above described, giving at starting the effect of a circuit containing a high resistance with a small self-induction, and therefore securing a large consumption of energy with a slightly-lagging current and at full speed operating as a low-resistance path with a small reactance. I accomplish this result by making the circuit through which the induced current flows a low-resistance winding, constituting, in effect, the primary of a transformer having a low-resistance secondary. At the moment of starting when the frequency of the current induced in the secondary member of the motor is at a maximum there will be a large consumption of energy in the transformer with a slightly-lagging current in the primary, due to the inductance that is necessarily present in such a device; but when the motor has obtained its normal speed the frequency of the current generated in the induced member of the motor will be so low that both the inductance of the transformer and the consumption of energy therein will be small. Both of these quantities may be still further reduced by so constructing the transformer that the reluctance of its magnetic circuit will be materially increased as the motor rises in speed, the construction for accomplishing this result being similar to that suggested in my prior application for reducing the self-induction of the winding constituting the inductive path.

My invention will be better understood by reference to the following description, taken in connection with the accompanying drawings, while its scope will be pointed out in the appended claims.

In the drawings, Figure 1 indicates diagrammatically an embodiment of my invention. Figs. 2 and 3 show the general construction of the transformer whose primary winding constitutes the circuit through which the current induced in the secondary member of the motor flows. Fig. 4 shows in end elevation the secondary or induced member of an induction-motor constructed according to my invention. Fig. 5 is a cross-section along the line 5 5 of Fig. 4, and Fig. 6 illustrates a modified transformer construction.

As illustrated in the drawings, my invention is appied to a three-phase motor.

In Fig. 1, *a b c* indicate the mains of a three-phase system supplied with current from any suitable source, A the primary or inducing winding of an induction-motor, and B the induced winding of the said motor. C is the transformer whose primary winding constitutes the single path through which the current generated in the induced winding of the motor flows. The primary winding comprises three coils or windings *d*, each connected at one end to one of the induced windings of the motor and at the other end to a common ring connection *e*. The transformer C may evidently be placed in any desired position relative to the motor structure; but in order to avoid the use of collector-rings when the induced member is the rotating member and in order that the entire apparatus may be combined in the single structure it will be found advisable to mount it on the motor itself. The transformer may be provided with an unchangeable magnetic circuit; but for reasons already explained it is desirable that this circuit be opened when the motor reaches full speed. In the preferred embodiment of my invention, therefore, the induced member of the motor is made the rotating member and the transformer, suitably constructed so that its magnetic circuit will be opened by the action of centrifugal force, is mounted thereon.

The transformer construction indicated in Fig. 1 and shown more clearly in Figs. 2 and 3 comprises a core *f*, having projecting portions around which the coils of the primary winding are wound surrounded by three cores c', c^2, and c^3, which normally completely close the magnetic circuits of the primary winding. As is indicated in Figs. 1 to 3, inclusive, the transformer is mounted upon a shaft, which may be the shaft of the motor itself. In Fig. 3 the members c' to c^3, inclusive, are shown separated from the member *f*, and in the preferred embodiment of my invention when the motor has reached normal speed the elements of the magnetic circuit of the transformer are positioned as is shown in this figure.

Figs. 4 and 5 show the actual construction of the transformer and its mounting with relation to the motor structure. In these figures I represents the induced member of the induction-motor mounted upon a shaft S. The member is of the usual construction, comprising a spider S′, supporting a laminated core L, through the slots of which the windings *g* are wound. In the construction shown a flanged portion D, bolted to the end of the spider, operates to support the overhanging ends of the windings. The transformer C is mounted on the shaft adjacent to the spider and with its movable members within the overhanging portion of the flange D. The element *f* of the transformer is keyed to the motor-shaft and is of the same general shape as the corresponding member indicated in Figs. 1 to 3. In the middle of each of the radially-projecting portions of this element *f* are mounted two pins *h h*, and these pins project into corresponding openings in each of the members c' c^2 c^3, thereby constituting means for guiding said members in their movement. The members c' c^2 c^3 are maintained normally in the position shown in Fig. 4 by means of the spring members *s*, their inner ends resting against the radially-projecting portions of the core *f* and their outer ends resting against one another. Before the motor reaches full speed, however, the movable members of the transformer are thrown outwardly by centrifugal force against the tension of the spring members, and at full speed the outer surfaces of the several movable members rest against the inner periphery of the flange D, thus opening to its widest extent the magnetic circuit of the transformer. The pins *h*, as well as the flange D, are preferably constructed of non-magnetic material in order that the magnetic circuit may have as high a reluctance as possible when the movable members of the transformer are in their extreme positions. The windings *d*, constituting the primary of the transformer, are mounted upon the projecting portions of the core *f* and rest against shoulders on said core. In order to maintain them in position against centrifugal force, a clamp *k* is provided on one side, while on the other side one end of each of the coils is riveted to a ring *e*, constituting a common connection for the ends of the three coils. The clamp *k* is suitably fastened in position, so that its projecting ends project over the outer sides of the coils *d*. The coils are, as is shown in cross-section in Fig. 5, wound with a few turns of heavy strip-copper conductor, and the other ends of the coils are connected, by means of leads i, to proper points in the winding on the induced member.

In order that the device C may operate as a transformer, it is evidently necessary that a secondary circuit or circuits be provided in inductive relation to the primary winding. I have found, however, that if the members constituting the magnetic circuit of the transformer are massive in construction and made of suitable material, unlaminated, distinct secondary windings are not required. The masses of magnetic material afford low-resistance conducting paths for eddy-currents set up therein, and these eddy-currents constitute the secondary currents of the transformer. For the magnetic circuit of the transformer I preferably use soft steel. When thus constructed, the transformer will have, in effect, a short-circuited secondary, even though it is not provided with a distinct secondary winding, and in embodying my invention in practical form I prefer to use a massive unlaminated core or cores for the magnetic circuit of the transformer, although a distinct secondary winding may be used, if desired. When the motor is starting, the frequency of the current induced in the secondary member of the motor is at a maximum and at the moment of starting is equal to the frequency of the current in the primary circuit of the motor. At this time the members of the transformer-core are in the position shown in the drawings, so that the reluctance of the magnetic circuit is low and the flux through the transformer-cores very large. Whenever the frequency of the current in the primary winding d is very high, the resistance losses in the shape of eddy-currents in the mass of the transformer-cores will be large. The effect on the motor at starting will be, therefore, nearly the same as if a large resistance were connected in circuit with the leads i in place of the winding of the transformer C. As the motor rises in speed the frequency of the current generated in the secondary member falls, the amount of energy dissipated in eddy-currents in the transformer-cores is reduced, and, finally, when the motor has reached its full speed the frequency of the current in the winding is so low that the eddy-current losses are very small. At the same time as the motor rises in speed the magnetic circuit of the transformer is opened, thus reducing the magnetic flux and tending to still further reduce the losses in the transformer-cores.

While I have shown in Figs. 4 and 5 a transformer having no distinct secondary windings, it is evidently within the scope of my invention to use a transformer having both primary and secondary windings, and such a construction I have indicated in Fig. 6 of the drawings, in which d represents, as before, one of the coils of the primary winding and l a copper band constituting a short-circuited winding interposed between the primary winding and the cores. When such a short-circuited winding is used, the cores may be laminated in place of the old solid construction shown in the drawings.

Although I have termed the device C a "transformer," I do not intend by such term to convey the idea that such device is without self-induction. I have used this term for the reason that it is due to the transformer action that the device is operative for the purposes of my invention.

In order to obtain a high-starting torque in an induction-motor, it is necessary that the effective resistance of the secondary member be increased without correspondingly increasing its inductance. The device which I have termed a "transformer" serves to increase both the inductance and the effective resistance of the secondary member; but it is so constructed that the former action is minimized and the latter increased as much as possible. Moreover, the inductance is proportional to the first power of the frequency in the circuit of the secondary member, while the effective resistance, or at least the part of it due to eddy-currents, is proportional to the second power of the frequency. At the moment of starting, when the frequency of the currents in the secondary member is high, the resistance effect of the transformer predominates, so that the starting torque is increased. As the motor rises in speed the frequency of currents generated in the secondary member falls, and therefore the impedance of the transformer is reduced. The impedance is still further decreased by the separating of the magnetic cores constituting the magnetic circuit. In the operation of the transformer there are present hysteresis losses, as well as losses due to eddy-currents. The losses due to hysteresis are also resistance losses and are proportional to the first power of the frequency of the currents in the induced member. The presence of hysteresis operates to make the resistance losses fall off more gradually, and therefore renders the starting of the motor more uniform.

The transformer construction illustrated in Figs. 4 and 5 of my present invention may be used for the inductive path in the arrangement described in my application Serial No. 726,910, and I therefore aim in this application to cover such construction however used.

Although I have illustrated my invention as applied to a three-phase motor, it is evident that it is applicable to any induction-motor irrespective of the number of phases, and although I have described a construction which is suitable for carrying out my invention I desire it to be understood that I am not limited to the particular structure shown and described, but that material changes may be made without departing from the spirit and scope of my invention.

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

1. Means for starting an induction-motor, consisting of a device, in circuit with the winding on the induced member of said motor, having a winding constituting a single path for the current induced in said motor-winding, said device comprising a coil or coils surrounding massive cores of magnetic material, and means for reducing the self-induction of said device as the speed of the motor increases.

2. Means for starting an induction-motor, consisting of a device, in circuit with the winding on the induced member of said motor, having a winding constituting a single path for the currents induced in said motor-winding, said device comprising a coil or coils surrounding massive cores of magnetic material, and means for increasing the reluctance of the magnetic circuit through said cores as the speed of the motor increases.

3. In a starting device for induction-motors, a core of magnetic material mounted on the shaft of said motor, a plurality of movable cores, means normally maintaining said movable cores in contact with one another and with the core on the shaft, and a winding surrounding said cores.

4. In a starting device for induction-motors, a core of magnetic material mounted on the shaft of said motor, a plurality of movable cores, means normally maintaining said movable cores in contact with one another and with the core on the shaft, means limiting the outward movement of said movable cores, and a winding surrounding the cores.

5. In combination with an induction-motor, a means for increasing the effective resistance of the secondary member at starting, consisting of a transformer in circuit with the winding of the secondary member, said transformer having a short-circuited secondary.

6. In combination with an induction-motor, means for increasing the effective resistance of the secondary member at starting, consisting of a transformer in circuit with the winding of the secondary member, and means controlled by the speed of the motor, for reducing the self-induction of said transformer.

7. In combination with an induction-motor, means for increasing the effective resistance of the secondary member at starting, consisting of a transformer in circuit with the winding of the secondary member, and means for increasing the reluctance of the magnetic circuit of the transformer as the speed of the motor increases.

In witness whereof I have hereunto set my hand this 28th day of June, 1900.

ARNALDO P. ZANI.

Witnesses:
BENJAMIN B. HULL,
MAUD R. MAY.