

Dec. 14, 1926.

J. D. LEWIS

1,610,455

METHOD AND APPARATUS FOR CONTROLLING ELECTRIC MOTORS

Filed Sept. 2, 1920

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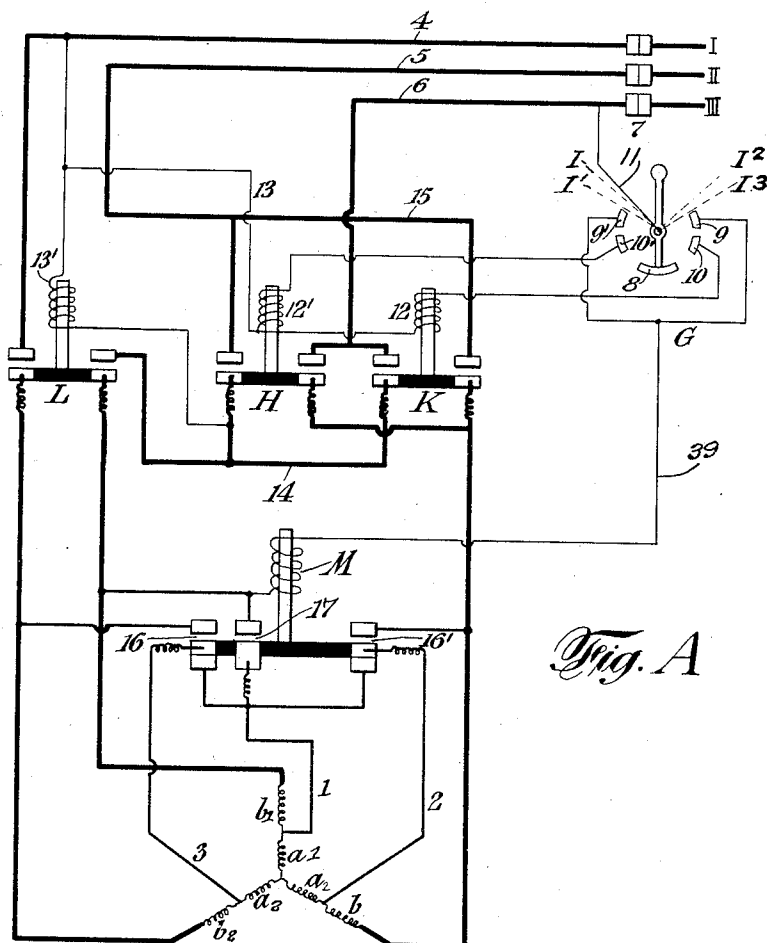
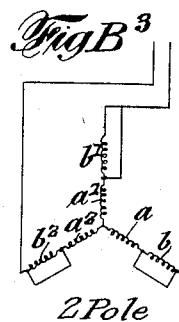
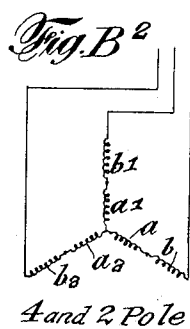
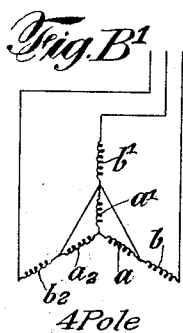


Fig. A



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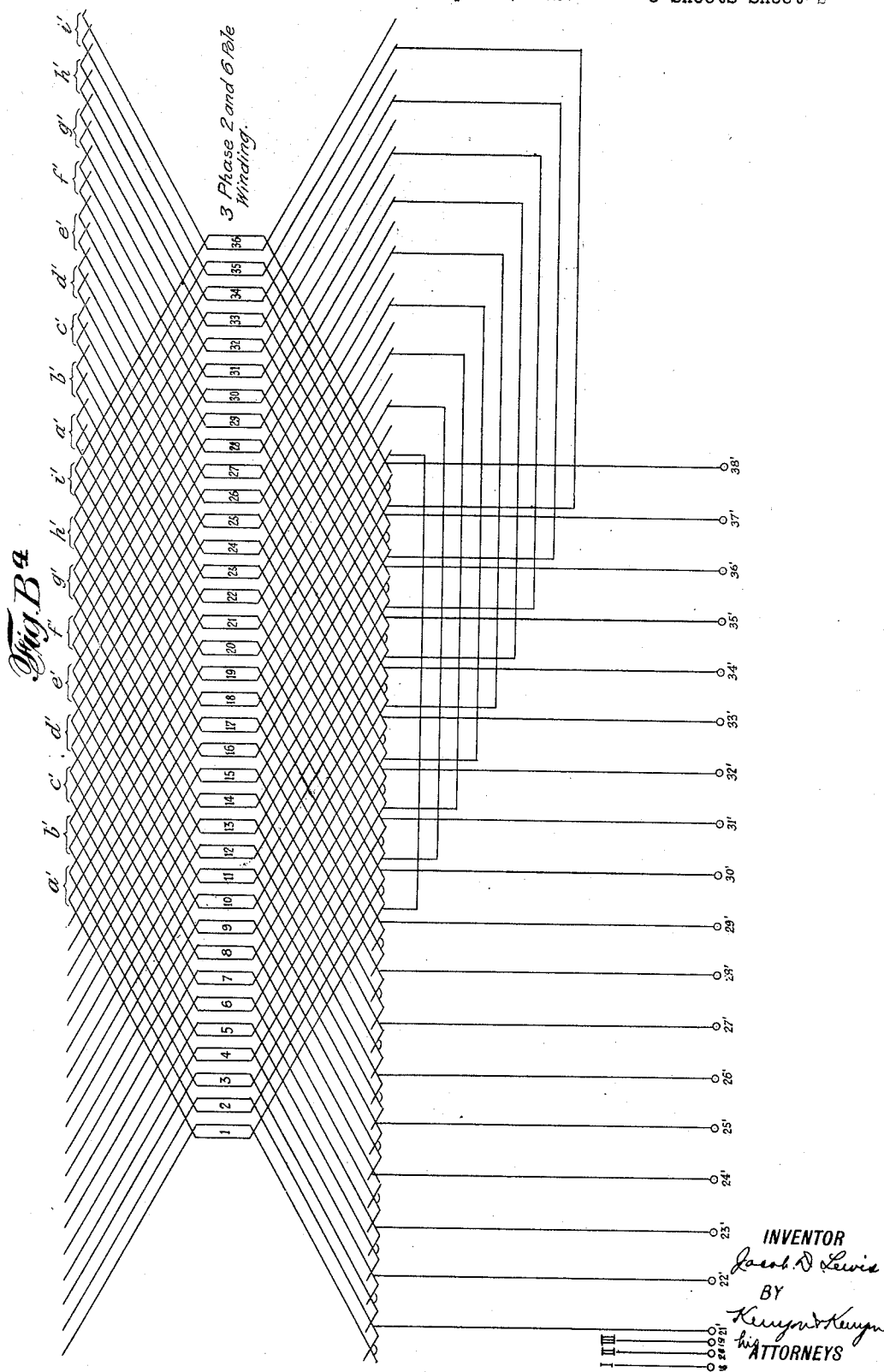
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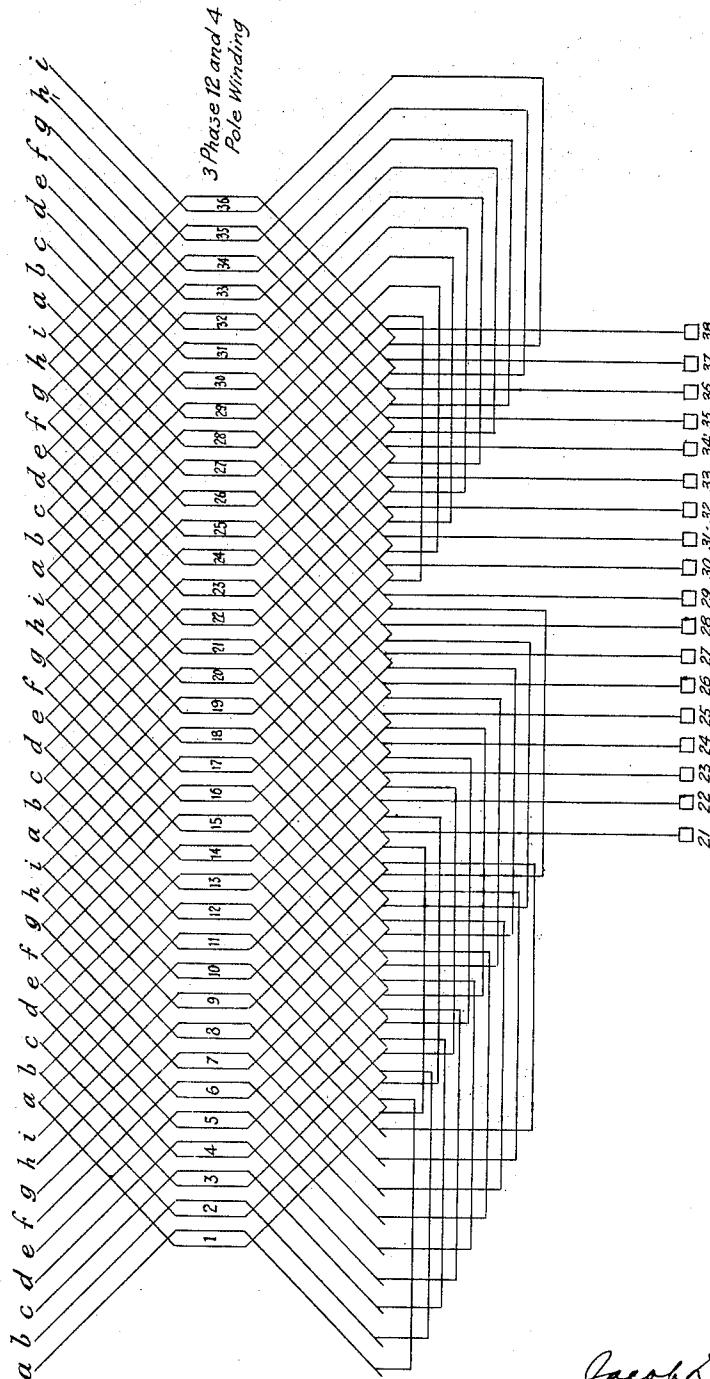
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Fig. B⁵



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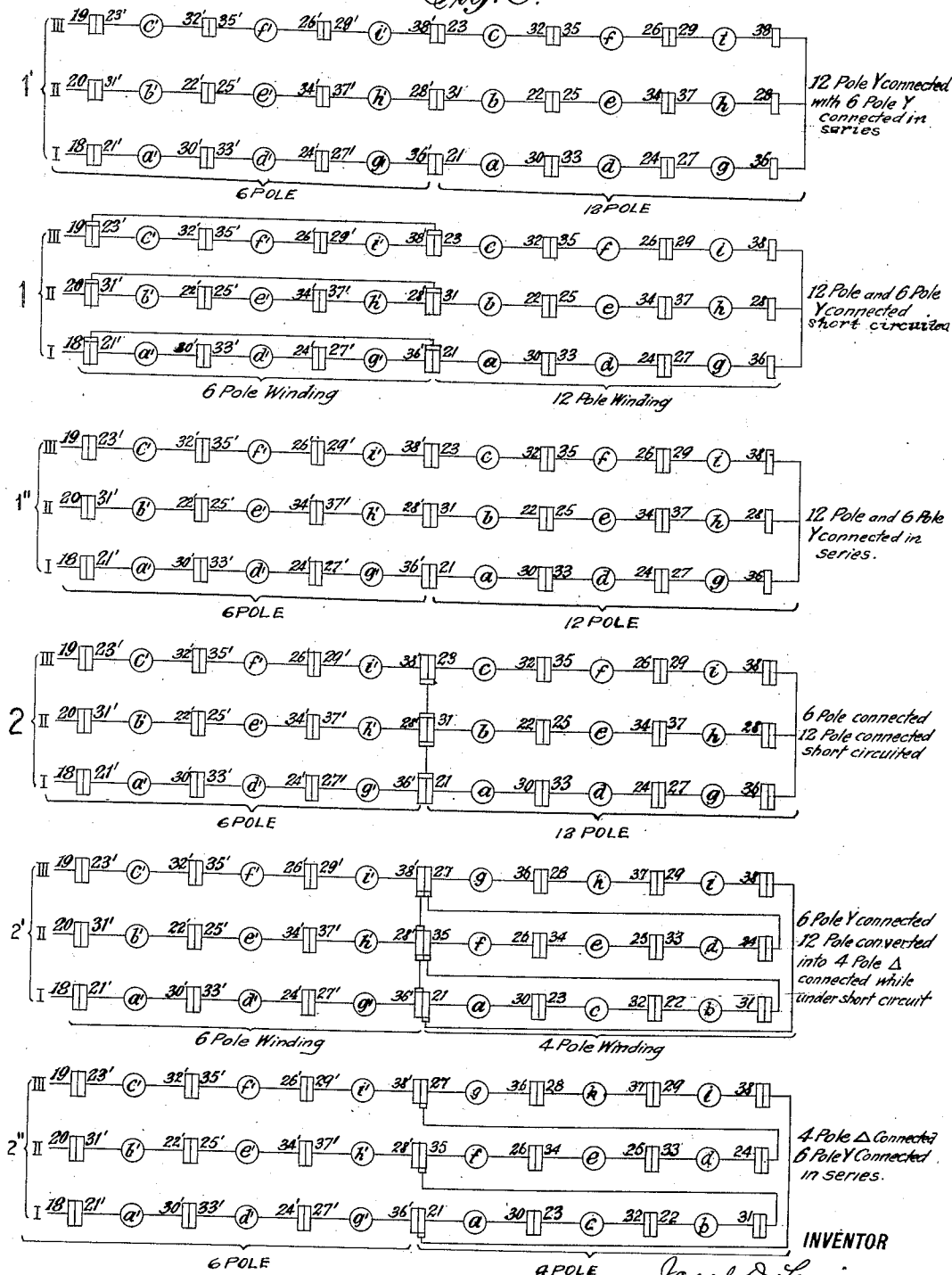
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Fig. C.



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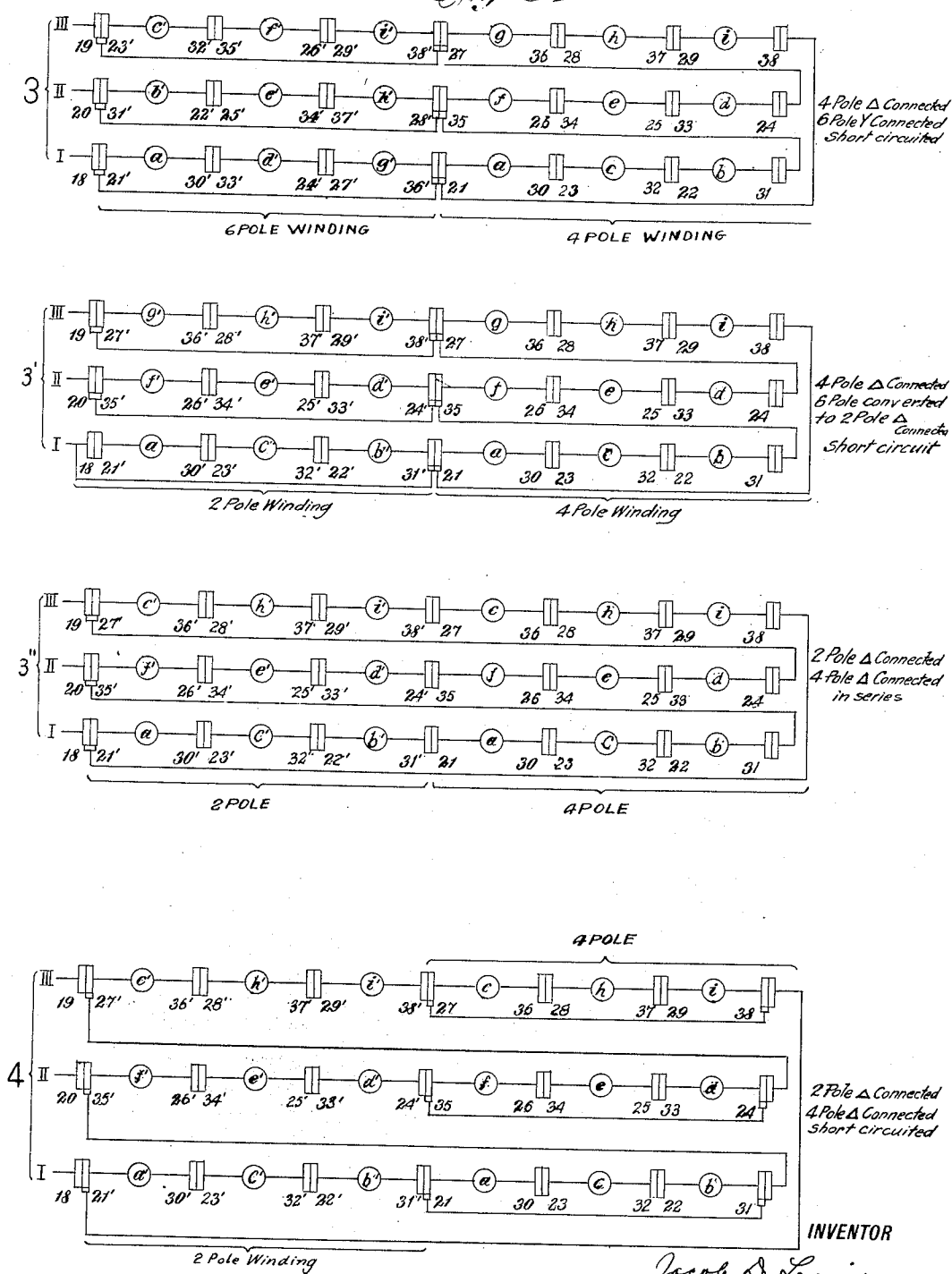
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Fig. C1



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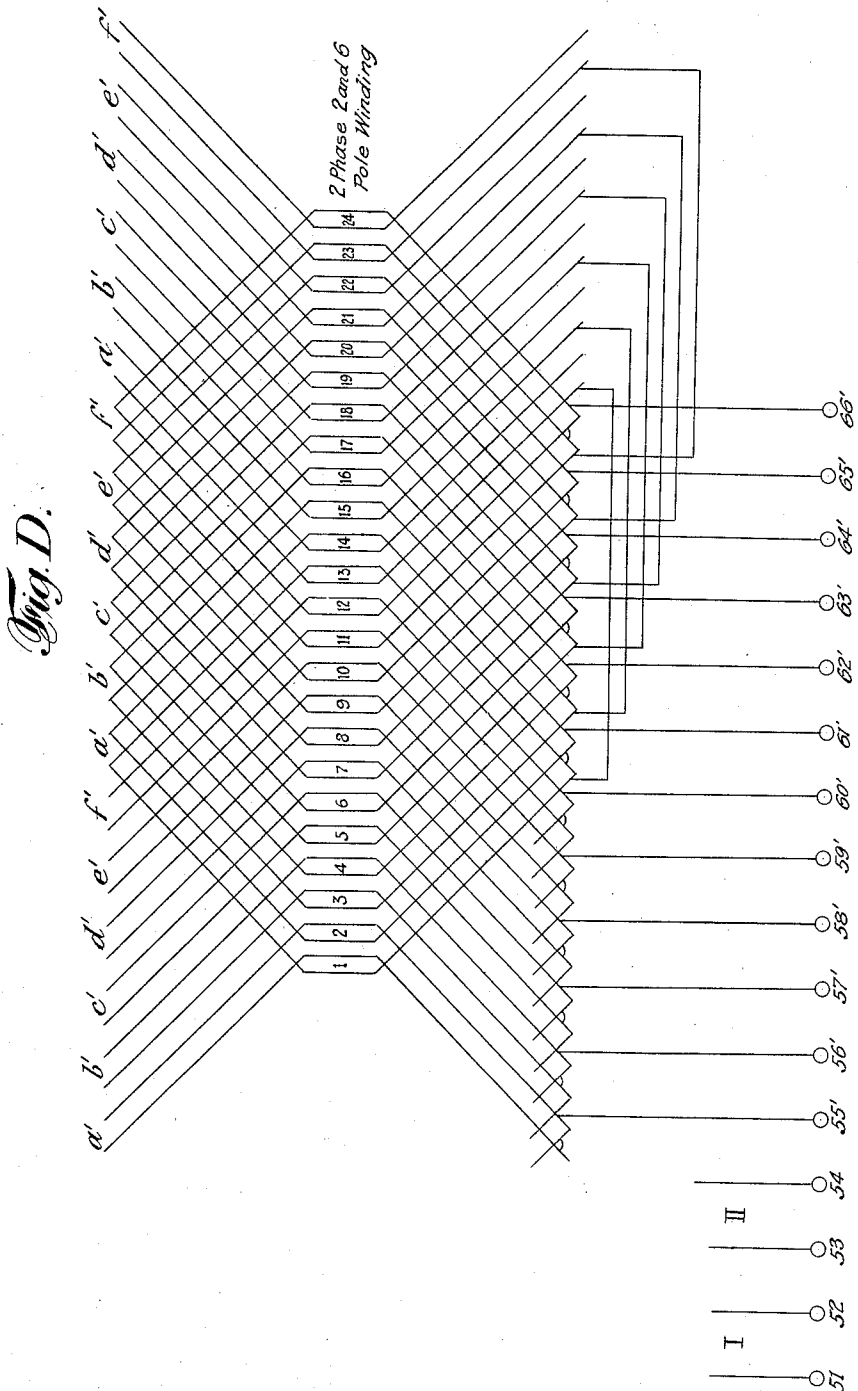
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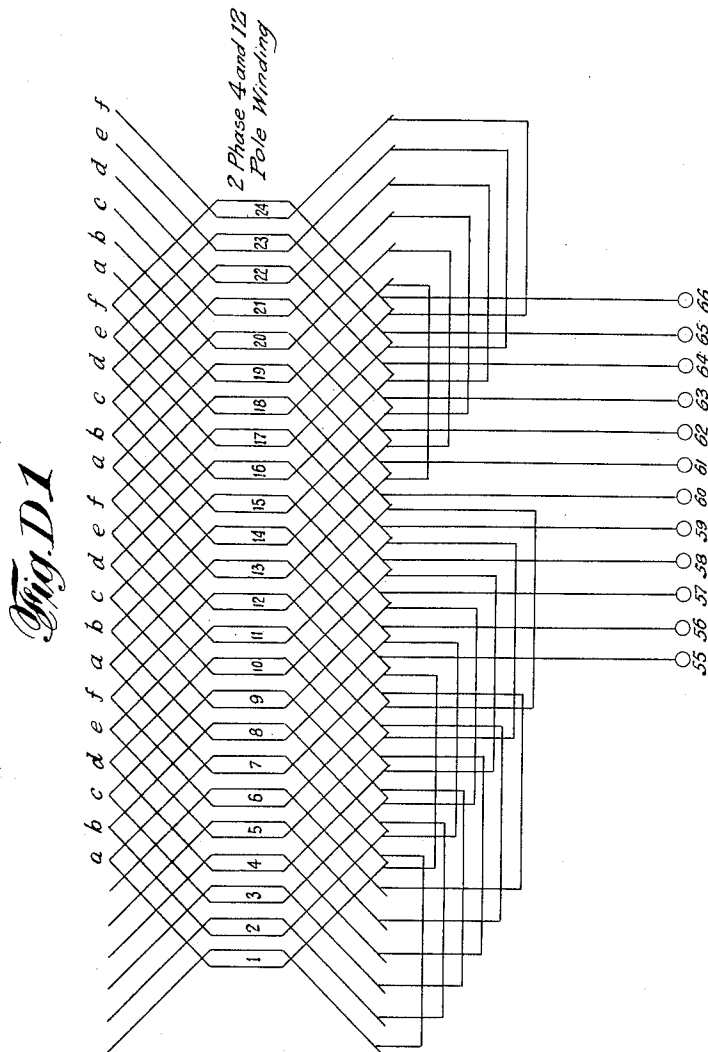
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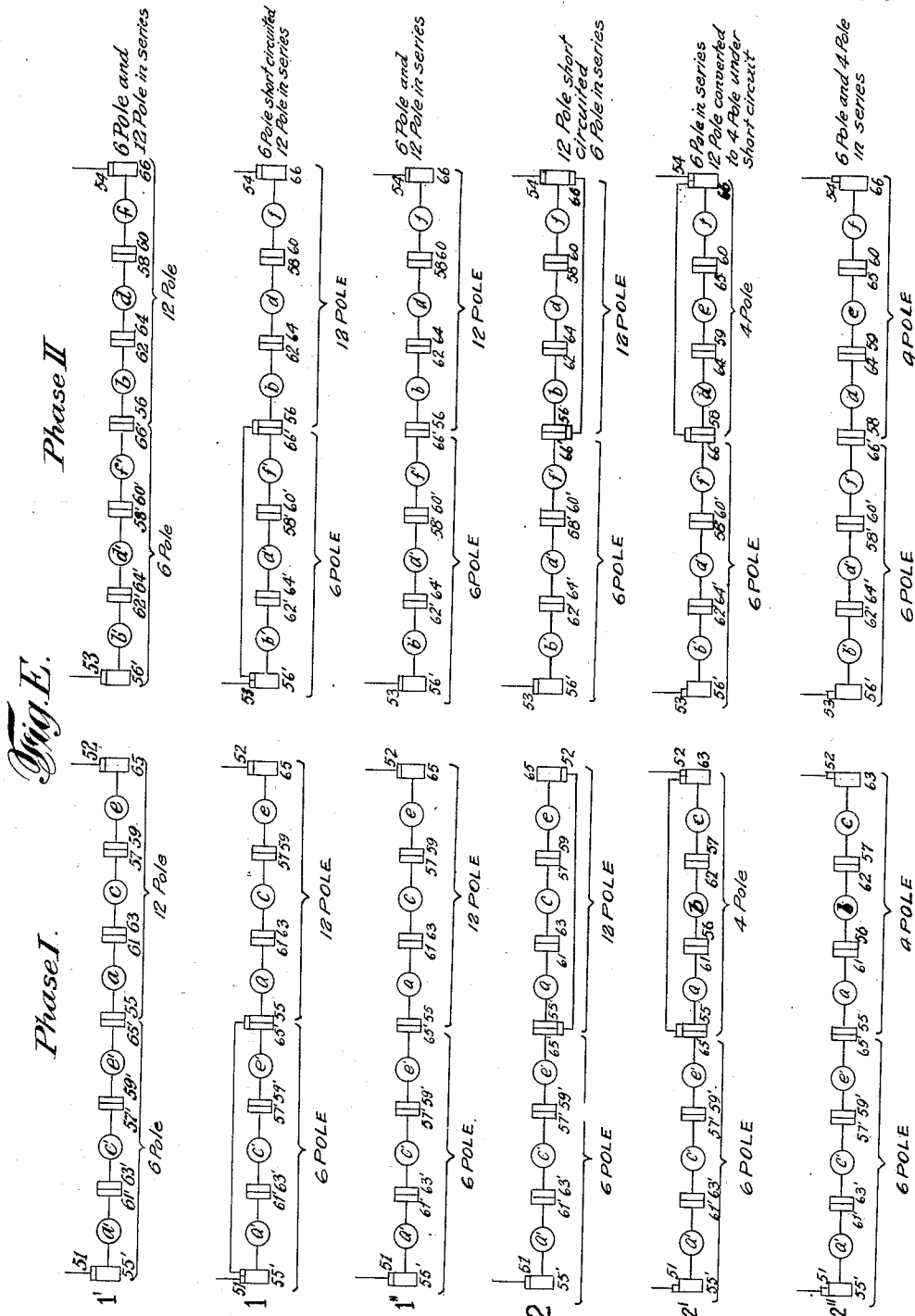
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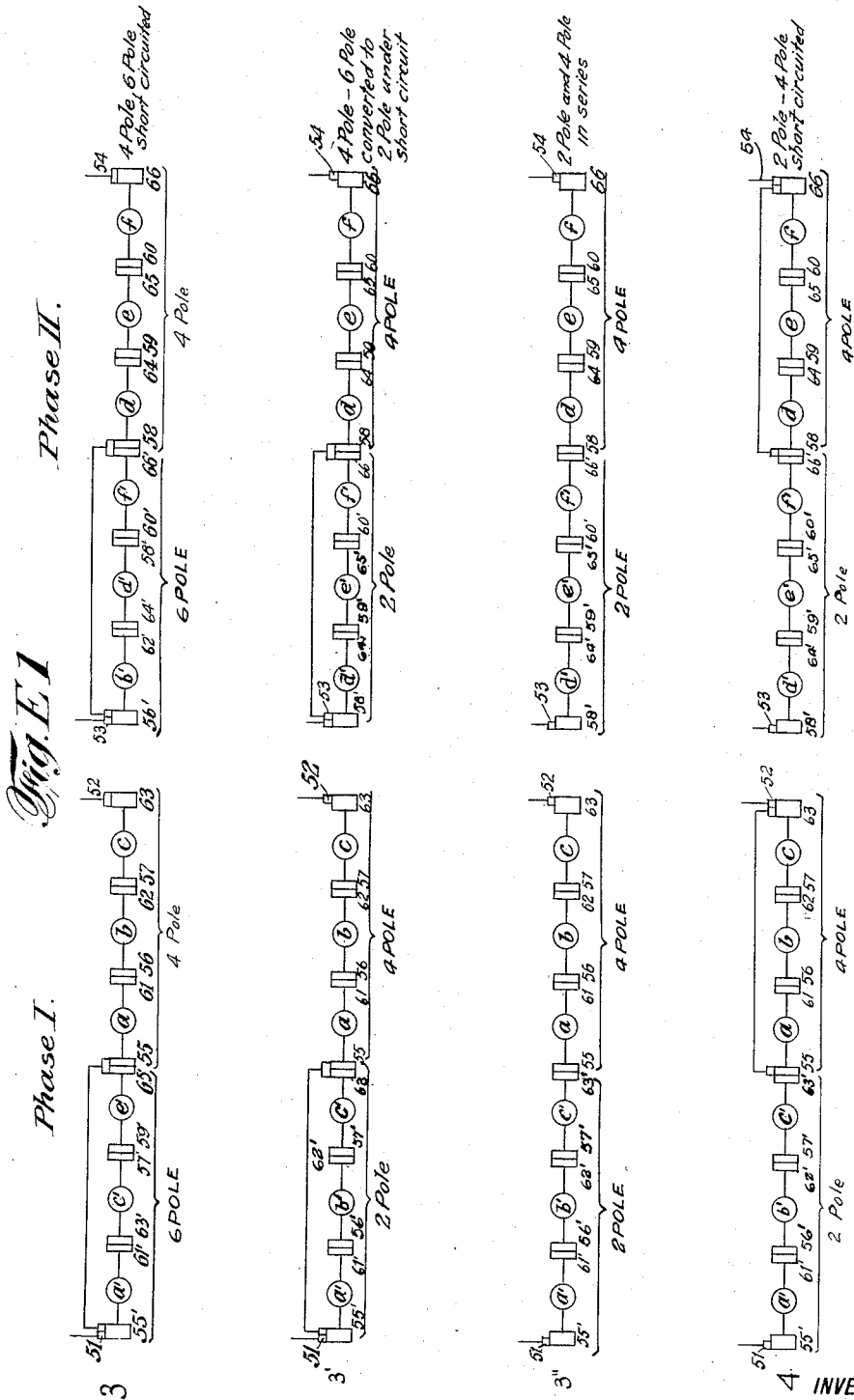
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METHOD AND APPARATUS FOR CONTROLLING ELECTRIC MOTORS

Filed Sept. 2, 1920

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UNITED STATES PATENT OFFICE.

JACOB D. LEWIS, OF YONKERS, NEW YORK, ASSIGNOR TO OTIS ELEVATOR COMPANY, A CORPORATION OF NEW JERSEY.

METHOD AND APPARATUS FOR CONTROLLING ELECTRIC MOTORS.

Continuation of application Serial No. 268,183, filed December 24, 1918. This application filed September 2, 1920. Serial No. 407,741.

My invention relates to alternating current electric motors of the asynchronous or induction type and particularly to methods and apparatus for varying the speed thereof.

5 In certain uses of induction motors, for example, in connection with elevators and hoists, it is necessary to maintain a continuous torque and in all uses where the load is constantly upon the motor any changes
10 of speed which involve breaking of connections give rise to excessive arcing or burning at the switch contacts and to the occurrence of excessive flows of current. It is an object of my invention to provide a method and
15 apparatus for varying the speed of induction motors without interruption of the torque and without such breaking of the contacts as gives the undesirable results above mentioned.

20 Another object of my invention is to provide an induction motor with a winding for producing a plurality of rotating fields respectively having different numbers of poles in which the effect of each number of poles
25 may be secured at different times, and a rotating field maintained during any change from one number of poles to another.

Another object of my invention is to provide an induction motor with a winding
30 having a plurality of parts for respectively producing different numbers of poles in which each part may be rendered effective alone to produce its respective number of poles and rotating field maintained while a
35 change is made from operation with one part of the winding to operation with another part of the winding.

Another object of my invention is to provide a winding for an induction motor consisting of a plurality of parts capable of being connected for simultaneous energization and arranged to produce rotating fields having respectively different numbers of poles,
40 for example, by having corresponding portions of the several parts connected in series, (i. e., with the portions of the parts respectively utilizing current of the same phase connected in series), in which a rotating field of one number of poles may be obtained
45 by rendering ineffective the parts of the windings arranged to produce another number, or other numbers, of poles. A further object of my invention being to insure the rendering effective of one part of the wind-

ing before rendering ineffective another part 55 so that while a change is made from one number of poles to another the main circuits are always connected and no breaking of main line contacts occurs and therefore there is no interruption of torque and no arcing
60 at contacts.

Another object of my invention is to provide an induction motor having a winding comprising a plurality of parts respectively arranged to produce different numbers of
65 poles with corresponding portions of the windings arranged for simultaneous energization wherein short circuiting all parts of the winding, except those producing the desired number of poles, produce the desired
70 speed. A further object of my invention is to arrange the short circuited portions of the windings so that any current induced in them by the non-short-circuited portions will be neutralized and of no harmful effect.
75

Another object of my invention is to provide an induction motor having a winding comprising a plurality of parts producing respectively rotating fields having different
80 numbers of poles each part being capable of being rendered operative and inoperative, and certain of said parts being capable of being rearranged to provide different number of poles—all without interrupting the torque or motor.
85

Another object of my invention is to provide a method of altering the connections and arrangement of circuits of an induction motor to secure a plurality of different definite speeds without interruption of the torque of the motor or breaking of main circuits.
90

Other and further objects will appear from the following description taken in connection with the accompanying drawings
95 and will be pointed out in the hereunto appended claims:

In the drawings in which like reference characters indicate similar parts, Figure A is a diagrammatic showing of a motor and means for changing the connections thereof to produce different speeds embodying my invention.
100

Figures B¹, B² and B³ are diagrammatic showings of the different connections produced by the controlling mechanisms illustrated in Figure A.
105

Figures B⁴ and B⁵ diagrammatically show

a stator winding for a three-phase motor which has parts susceptible of arrangement so as to produce respectively 2 and 6 poles and 4 and 12 poles.

5 Figures C and C¹ are diagrammatic showings of the manner of shifting the connections of the winding shown in Figures B⁴ and B⁵ in order to secure, in accordance with my invention, four different speeds.

10 Figures D and D¹ together diagrammatically show a two-phase stator winding for an induction motor and having parts which are respectively susceptible of arrangement to produce 2 and 6 pole fields and 4 and 12 pole fields.

15 Figures E and E¹ together diagrammatically show the manner of altering the connections of the winding shown in Figures D and D¹ in order to produce 4 speeds in accordance with my invention.

20 One construction embodying my invention includes a winding for induction motors which has parts to produce respectively different numbers of poles, and any of these
25 parts may be so arranged, and provided with means such that its connections may be so changed that it will produce still another number or other numbers of poles. In such an exemplary construction a motor may
30 have a winding comprising two parts connected in series producing respectively different numbers of poles. One part can be rendered ineffective to produce its number of poles, as by short-circuiting, and then
35 while the two parts remain connected in series the short-circuit may be removed from the first part and placed over the other part so that the other number of poles is produced. Furthermore while one of the parts
40 is short-circuited its connections may be rearranged in various ways so that a number of poles may be produced by it when the short circuit is removed from it, different from the number formerly produced by it.
45 And during all of these changes the motor connections are never broken and the torque is continuous.

50 In carrying out my invention a stator winding of an induction motor comprising a plurality of parts respectively for producing different numbers of poles has the portions of the two windings utilized by the same phase connected in series. For the purpose
55 of fully disclosing my invention I hereinafter describe in detail the manner of utilizing certain stator windings but it is to be understood that any stator windings may be used which may be so connected as to produce respectively different numbers of poles
60 and which may each be susceptible of rearrangement in themselves to produce different numbers of poles such, for example, as windings made in accordance with the disclosures of my copending application Serial No. 333,490 filed October 27, 1919.

Certain of the features disclosed herein are disclosed in my co-pending application Serial No. 268,183 filed December, 1918, of which this application is a continuation.

70 As a simple embodiment of my invention there is illustrated in Figure A a winding for an induction motor and controlling means for changing the number of poles produced by the winding. The stator winding comprises a three-phase circuit having
75 the coils or groups of coils, a , a^1 , and a^2 for producing one number of poles and having respectively connected in series therewith the coils or groups of coils b , b^1 and b^2 for producing a higher number of poles. Three-
80 phase alternating current is carried into the motor by the conductors 4, 5 and 6 which are provided with a main line switch 7. The flow of current to the motor is controlled by the switch G which might be positioned in an elevator car. The reversing
85 switches H and K as well as line switch L are controlled by the operating switch G. The operating switch G comprises a controller handle carrying a contact 8 which
90 when swung in one direction will sweep over the contacts 9 and 10 and when swung in the other direction will swing over the contacts 9' and 10'. If the operating handle is swung to the left to the position I the contact 8 will be swung into contact with the member 10 and current will flow from the main line wire 6 through the conductor 11 to the controller arm through the contact 10 to the relay 12 which will draw up the armature of the reversing switch K. From the relay 12 the connection is made through the wire 13 back to the main line wire 4. When the armature of the reversing switch K is raised the motor will be connected for one direction of operation as follows. The current flowing through the conductor 6 will be carried to the conductor 14 and thence to the terminal of the stator coils a^1 and b^1 . The conductor 14 being energized, the current will flow from main line wire 6 through the relay 13' to the main line wire 4 and draw up the armature of the main switch L thus connecting the main line wire 5 to the conductor 15 which is in turn connected to the terminal of the stator coils b and a through the reversing switch K. The main line wire 4 will also be connected to the terminal of the stator coils b^2 — a^2 by the switch L. Now the speed relay M is not energized and will be in the position shown so that conductor 1 leading from a point between the coils a^1 and b^1 , the conductor 2 leading from a point between the coils a and b and the conductor 3 leading from a point between the coils a^2 and b^2 will form a short circuit around the coils a , a^1 and a^2 producing the connection shown in Figure B¹ so that the motor will be operating on the coils b , b^1 and b^2 , the higher number of
130

coils giving the lower speed. If now the operating lever is pushed further to the left to the position I^1 it will bridge the contacts 9 and 10 thus energizing the speed relay M through conductor 39 and drawing up the armature thereof closing the contacts 16, 17 and 16'. It will then be seen that the conductor 1 leading from the point between the coils a^1 and b^1 now leads back through the contact 17 to the conductor 14 so that the coil b^1 is short circuited. In like manner the conductor 2 short circuits the coil b and the conductor 3 short circuits the coil b^2 producing the connections shown in Figure B³. It will be apparent that movement of the operating lever of the switch G to the right to the positions I^2 , I^3 , will energize the relay 12' so as to connect the windings in a different relation and produce a different direction of running.

It will now be apparent that an induction motor having a winding with two parts respectively in series and for producing different numbers of poles has been so connected as to start up on the part producing a higher number of poles, and the connections changed so as to operate the motor finally on the windings producing the lower number of poles and that the torque of the motor has not been interrupted during the transition because during the slight interval while the speed relay M is shifting from one position to another the parts of the winding for the higher and lower pole numbers are in series as shown in diagram Figure B². It will be observed that in the construction described the speed controlling switch M is predisposed by gravity or equivalent expedient to a position wherein the winding-part producing a higher number of poles will alone be energized, the other part being rendered ineffective by short-circuit when the current is first supplied to the motor, and that the switch M may be operated to a position wherein the winding-part producing the higher number of poles is rendered inoperative by short-circuiting and then the part producing the lower number of poles is alone effective. It will also be observed that during this transition from the use of the higher number of poles alone to the use of the lower number of poles alone the part producing the lower number of poles is energized before the part producing the higher number of poles is de-energized.

It has been proposed heretofore to provide an induction motor with one winding producing a higher number of poles and another winding to produce a lower number of poles and to energize both windings during the starting of the motor and to then de-energize the winding producing the lower number of poles so that the motor will operate only with the winding producing the higher number of poles, but it will be apparent that ac-

cording to my invention an induction motor may be operated at a plurality of speeds which are definite in that they are produced by poles normally arranged, i. e., equidistantly spaced, at each speed, the lower speed occurring when the winding-part producing a higher number of poles is energized and the higher speed occurring when the winding-part producing the lower number of poles is energized.

If two parts of a winding produce respectively numbers of poles bearing an even ratio to one another, then the neutralization of the voltages produced in the short-circuited part of the winding by the current passing through the energized part of the winding is brought about as follows:

(a) If the motor is running at a low speed with the part of the winding producing a low number of poles short-circuited, there will be no voltage induced in the coils producing the lower number of poles, because the coils producing the lower number of poles each embrace 360 electrical degrees or the equivalent thereof of the part of the winding producing the higher number of poles, therefore the high speed winding can be connected with Y or Δ connection while short-circuited.

(b) If the motor is operating on the part of the winding producing the lower number of poles some voltage will be induced in the part of the winding producing the higher number of poles. In order to safely short-circuit the part of the winding producing the higher number of poles it must be Y-connected, or it may be Δ connected if the coils of the part of the winding producing the higher number of poles are arranged in groups as shown, so that voltages induced in these groups of the part of the winding producing the higher number of poles neutralize one another and the voltage at the short-circuit point is zero. It will be apparent that if the coils are of full pitch, the coils of the part of the winding producing the higher number of poles will embrace 90 electrical degrees of the part of the winding producing the lower number of poles, and therefore the part of the winding producing the higher number of poles must be connected Y or arranged in groups, and the groups connected as above described and as shown, so that the voltages induced in the various groups will neutralize one another.

If two parts of a winding produce respectively numbers of poles bearing an odd ratio to one another, such, for example, as 1:3, 4:6, etc., then the voltages induced in the short-circuited winding by the energized part of the winding will be disposed of as follows:

(a) If the motor is operating on the part of the winding producing a higher number of poles, the voltage induced in each coil of

that part of the winding producing the lower number of poles is the same as the impressed voltage upon each coil of that part of the winding producing the higher number of poles. If the number of turns in each coil is the same, the short-circuited part of the winding producing the lower number of poles must be Y-connected or the pitch of each coil of that part of the winding producing the lower number of poles must be lengthened or shortened so that it will embrace 360 electrical degrees or the equivalent thereof of that part of the winding producing the higher number of poles. The manner of employing coils of shorter or longer pitch than the pole pitch is disclosed in my co-pending application above identified.

(b) If the motor is operating on that part of the winding producing a lower number of poles, some voltage will be induced in each coil of that part of the winding producing the higher number of poles and the harmful effect of these voltages are avoided by connecting that part of the winding producing the higher number of poles in a Y-connection or by connecting them in a Δ connection and arranging the coils in groups and distributing the groups as shown so that the voltages produced in these groups neutralize one another and the voltage at the short-circuit point is zero.

While I have so far disclosed the idea of providing a plurality of winding-parts producing different speeds and de-energizing one winding-part and energizing the other in order to obtain different speeds, but always energizing another part before any given part is de-energized, my invention also includes the idea of having each of the parts so arranged that while it is de-energized the internal connections thereof may be changed so that it will itself produce a plurality of numbers of poles each different from the numbers of poles produced by any other part even though the connections of such other parts or part may be changed so that they individually produce a plurality of numbers of poles.

In order to illustrate and disclose the manner of carrying out the idea of changing the connections of each part of a winding to produce different numbers of poles there are illustrated in Figures B⁴ and B⁵ two parts of a 3-phase winding that may be embodied in the same motor. The part shown in Figure B⁴ has certain leads carried out which are numbered 21' to 38' so that it may be changed from a 2 pole to a 6 pole winding-part and the part shown in Figure B⁵ has certain leads carried out which are numbered 21 to 38 so that it may be changed from a 4 pole to a 12 pole winding-part. The contacts 18, 20 and 19 are respectively for connection of the three supply wires I, II and III. Inasmuch as the mak-

ing of a drum controller to produce a number of connections is merely a matter of design after the connections are disclosed I have refrained from showing any drawings of controllers but in Figures C and C¹ I have shown the manner of connecting up the various lettered groups of coils by indicating what terminals are to be brought together so as to carry out 4 different changes of speed in accordance with my invention. In Figure C the Diagram 1' shows the manner of connecting the coils of parts B⁴ and B⁵ so that a twelve pole winding and a six pole winding are connected in series. This will be the arrangement of the connections for starting. It will be apparent that when winding-parts producing different numbers of poles are both energized the motor will come up to a speed corresponding to the higher number of poles and when the part producing the lower number of poles attempts to increase the speed there will be a generator action in the part producing the higher number of poles which will restrain the motor against a further increase of speed.

The first definite speed is produced without interrupting the torque of the motor by arranging the connections as shown in Diagram 1 of Figure C. This change consists in short circuiting the winding producing six poles. The next speed will be produced by the six pole winding alone and in order to reach this condition without break of motor connections there is a transitional stage shown in Diagram 1 wherein the six and twelve pole parts are in series.

Diagram 2 shows the second speed wherein the motor is operating on the six pole part and the twelve pole part is short circuited. It will be noted that this speed is arrived at by energizing the part producing the desired speed before the part producing the former speed is de-energized. The next speed desired will be that produced by four poles and therefore in Diagram 2' I have shown the manner of altering the connections of the part Figure B⁵ to change it from a twelve pole winding to a four pole winding. These changes occur while the part is de-energized. Before de-energizing the six pole part the four pole part is energized and Diagram 2'' shows this transitional condition. Diagram 3 Figure C¹ shows the condition wherein the motor is operating on a four pole winding-part which is Δ connected so as to produce the proper flux distribution in accordance with the principles disclosed in my co-pending application above identified. In this case the six pole part is short-circuited.

The next speed desired is that produced by two poles and therefore I have shown in Diagram 3' the manner of re-arranging the connections of B⁴ part while that part is

de-energized in order to produce 2 poles. In order to avoid interruption of the torque in the motor and the undesirable effects above mentioned, it is necessary to energize this B⁴ part before the four pole part B⁵ is de-energized and the connections for producing this transitional condition are indicated in Diagram 3''.

The fourth speed obtained by the use of 2 poles in Δ connection is then obtained by de-energizing the 4 pole part B⁵ and the Diagram 4 shows the connections to produce this result.

My invention also includes the idea of applying my invention to 2-phase motors and in Figure D I have shown a 2-phase winding having parts for producing 2 and 6 poles and in Figure D¹ 4 and 12 poles. In Figure D the leads are carried out from the windings, and numbered 55' to 66' and in Figure D¹ are numbered 55 to 66, so that the connections of the windings may be changed to cause the windings to produce the different numbers of poles mentioned. In Figure D the first-phase conductors are brought in to the contacts 51 and 52 and the second-phase conductors to the contacts 53 and 54. It will be observed that changes in the connections between the leads which are brought out change the connections of groups of coils, the coils of one and the same group having the same letter. In Figures E and E¹ I have shown a series of diagrams which disclose the manner of altering the connections of the two windings shown in Figures D and D¹ in order to produce four different speeds, the different speeds being produced in accordance with the principles of my invention. It will be seen from the diagrams of Figures E and E² that the transitions from one speed to the other are carried out without the interruption of the torque of the motor just as in the case of the 3-phase motor above described.

While it has been proposed, in the prior art, to have in an induction motor windings producing different numbers of poles and using both windings in starting and then rendering the winding producing the lower number of poles inoperative after the speed corresponding to the higher number of poles is obtained as above mentioned my invention relates to the idea of providing a plurality of windings each producing a different number of poles (and each of these windings may be rearranged in itself to produce several numbers of poles) and in starting rendering only one of all these windings operative and in running also, except for a brief transition from one winding to another, but without interrupting the torque of the motor because the succeeding winding is energized before the preceding winding is de-energized. And while I have illustrated and described 2 and 3-phase windings sus-

ceptible of alternation to effect certain speed ratios it is apparent that the substitution of any other windings such, for example, as those disclosed in my co-pending application above identified constitutes merely a matter of engineering. My invention therefore is not limited to the exact details of the construction above described but is defined in the hereunto appended claims.

Having thus described my invention, what I claim as new and desire to secure by Letters Patent is:

1. In combination, a multi-speed induction motor having independent inducing windings for producing different speeds, means for energizing the windings for any one speed without energizing those for the other speeds, and means for connecting said independent windings in series to the supply circuit.

2. In combination, a multi-speed induction motor having independent inducing windings for producing different speeds, means for energizing the windings for any one speed without energizing those for the other speeds, means for changing the energization from one winding to another and means for connecting said windings in series to the supply circuit during said change.

3. In combination, a multi-speed induction motor having independent inducing windings for producing different speeds, and means for selectively short-circuiting the windings for the different speeds, said windings being in series during the transition period from one speed to another.

4. In combination, a multi-speed induction motor having two independent inducing windings of different pole numbers, and means for fully energizing either one of said windings and for short-circuiting the other to cause the motor to run at either one of two speeds, determined by the pole number of the winding energized, and for energizing both of said windings in series relation and thereafter short-circuiting said one winding and fully energizing the other to change from said one speed to the other.

5. In combination, a multi-speed induction motor having two independent inducing windings of different pole numbers, and means for alternatively fully energizing either one of said windings while short-circuiting the other winding to cause the motor to run at either one of two speeds determined by the pole number of the winding energized, said means comprising means for energizing both of said windings in series relation during the transition from one speed to the other.

6. In combination, a multi-speed induction motor having at least two independent inducing windings for producing different speeds, means for selectively short-circuiting the windings for the different speeds,

and means for reconnecting at least one of said windings while short-circuited to produce another different speed.

7. In an induction motor, a winding comprising a plurality of parts for respectively producing different numbers of poles and series connected for energization, and means for rendering any of said parts inoperative whereby a plurality of definite speeds is secured, one of said parts being susceptible of rearrangement while inoperative to produce different numbers of poles.

8. In combination, an induction motor having a winding comprising parts for respectively producing different numbers of poles and connected for simultaneous energization, and means including a switch biased to a position wherein said means renders inoperative one of said parts and movable to a position wherein said means renders inoperative the other of said parts.

9. The method of producing different speeds in an induction motor which consists in arranging the connection of the inducing winding to cause different parts of it to produce respectively a plurality of numbers of poles, connecting said parts in series for energization, and rendering each part operative alone by rendering all other parts inoperative.

10. The method of producing different speeds in an induction motor which consists in arranging the connections of the winding to cause different parts of it to produce respectively a plurality of numbers of poles, connecting said parts in series for energization, rendering each part operative alone by rendering all other parts inoperative, and altering the connections of any one of said parts to arrange it to produce different numbers of poles while said part is inoperative.

11. The method of producing different

speeds in an induction motor which consists in connecting the inducing winding to provide parts producing respectively different numbers of poles, connecting said parts in series for energization, and selectively de-energizing any or all but one of said parts according to the speed desired.

12. The method of producing different speeds in an induction motor which consists in connecting the winding to provide parts producing respectively different numbers of poles, connecting said parts in series for energization, and selectively deenergizing any or all but one of said parts according to the speed desired, and rearranging the connections of any deenergized part to produce different numbers of poles and reenergizing such part.

13. The method of producing different speeds in an induction motor which consists in connecting the winding to provide parts producing respectively different numbers of poles, connecting said parts in series for energization, and short-circuiting any or all but one of said parts according to the speed desired, insuring that any part to be short-circuited be previously arranged in Y-connection.

14. The method of producing different speeds in an induction motor which consists in connecting the winding to provide parts producing respectively different numbers of poles, connecting said parts in series for energization, and short-circuiting any or all but one of said parts according to the speed desired, insuring that any part to be short-circuited be previously arranged so that voltages induced therein will be neutralized.

In testimony whereof, I have signed my name to this specification.

JACOB D. LEWIS.